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PHYSICS.—*On understanding electric breakdown in solids.*[1] R. J. SEEGER, The George Washington University.

The seventeenth century marks the beginning of the modern study of electricity and magnetism. In the year 1600 William Gilbert of Colchester published his monumental work *De magnete, magneticisque corporibus, et de magno magnete tellure.* In this book he mentioned 20 materials, such as glass, which behave like amber in that when they are rubbed they have the power of attracting light objects. The Greek word for amber being *electron* (ἤλεκτρον), he designated these materials by the word electric, i.e., like amber (it is only later that such bodies were believed to be charged or loaded with a quasi-fluid electricity). He remarked further that certain other substances, notably metals, do not have this characteristic feature. They, therefore, may be regarded as being nonelectric.

More than a century later Stephen Gray pointed out that this distinction between electric and nonelectric substances is not fundamental but rather accidental in that it depends to a great degree upon another physical property, namely, conduction. For example, if a piece of glass is brought temporarily into contact with an electrified body (one that has been made electric), upon separation the glass itself will not be electrified. On the other hand, if a metal is brought temporarily into contact with an electrified body (with proper precautions), it will be found to be electrified upon removal. In the latter case there has been a transfer of some of the electrification by contact—a process known as conduction. It is this very property, indeed, that causes the electrification of a metal to be commonly unnoticed when the metal is held in one's hand and rubbed. In this instance the electrification is immediately shared with the much larger earth by way of the person's body. If precaution is taken to prevent such a transfer, a metal or any other substance can be made electric by being rubbed. What Gilbert called electrics are essentially nonconductors; so-called nonelectrics are in reality conductors.

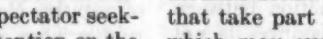
Nowadays it is customary to differentiate conductors and nonconductors (more commonly called insulators) in terms of their ability to carry an electric current. Thus if a conductor connects a source of positive electrification (the state of polished glass when rubbed with silk) with a source of negative electrification (the state of hard rubber when rubbed with fur), it is said to carry an electric current, which is manifested in thermal, magnetic, and chemical effects (under certain conditions). No matter how weak the electrification (measured by its so-called voltage), there will always be an electric current—correspondingly weak, of course. On the other hand, if an insulator such as table salt (or any other alkali halide) is made to connect the same sources of electrification, it will be found to carry no electric current. Even though the voltage is considerably increased, an electric current is barely detectable. Only when the voltage across each centimeter of material is about 100,000 volts is there a significant current, which slowly increases with still further voltage increments.

[1] Address of the retiring president of the Philosophical Society of Washington, delivered at the 1[illegible]0th meeting of the Society, January 15, 1944, when the author was on War Leave with the Bureau of Ordnance, Navy Department. Received April 26, 1946.

In the neighborhood of 500,000 to 3,000,000 volts per centimeter, however, the electric current suddenly becomes appreciable. The insulator then behaves like a conductor. The understanding of this phenomenon of electric breakdown is the purpose of our brief survey this evening.

First of all, however, a digression may be permissible in order to clarify our terms. What do we mean by the phrase understanding a phenomenon? In this regard there is an interesting expression used by Plutarch to characterize the spirit of early Greek astronomy. The mathematical astronomer Aristarchos of Samos is described by him as seeking "to save the phenomena" of the heavens. For the nightly pageant of the sky seems even now to be readily understandable in terms of circular motions of the sun, the moon, and the stars about the earth, but on the face of it there is one disturbing anomaly—the irregular behavior of the planets. These wanderers, as their name signifies, move apparently in loops. The essential need, therefore, is to save face, to make the idea of celestial circular motion safe despite the appearances, or—to use the Greek word for appearances—to save the phenomena (*σώζειν τὰ φαινόμενα*). Now how is it possible thus to save a phenomenon? By getting a proper point of view—usually a wider one from a higher level—that will merge both the regular appearances and the irregular appearances into a single scene! In this connection one is reminded of a spectator seeking a high seat to focus his attention on the stage of a Greek amphitheater. Indeed, it is noteworthy that the etymological root of the word *theater* is the same as that of the word *theory*, namely a view. When we are theorizing, we are simply trying to get a proper point of view. Thus we can save the phenomenon of electric breakdown by arranging a more inclusive theory which will enable us to view wholly the regularities of conductors and of insulators together with the apparent irregularity of electric breakdown. Our problem can be formulated briefly as follows: how is it theoretically possible for an insulator to become a conductor? In order to answer this question, however, we need to review theoretically two other questions: What is a conductor? What is an insulator?

We begin by noting that most of the chemical elements are metals, and consequently conductors. Hence we may profitably examine a metal as a typical conductor. Now almost any textbook of general physics makes the differentiation that metallic conductors contain electrons (minute masses with negative electrification) that are free to move, whereas insulators do not, so that an electric current is equivalent to a continuous electronic shift in an electric field of force. Leaving aside for the moment the precise validity of this distinction, we pursue the clue that the macrocosmic property of conduction may be explicable in terms of these universal elementary particles. Incidentally, it is generally recognized, of course, that ascertaining the attributes of such elementary particles is properly the domain of physics, but it is less emphasized that the theoretical interpretation of the properties of ordinary matter in terms of these very same particles is an equally important physical problem (less glamorous, but not less significant). That such electrons may be inside a metal is an experimental inference from the fact that the jarring of a metal by heat, by ultraviolet light, or by X-rays may result in the emission of electrons. Moreover, it is reasonable to regard these electrons as the loosely held ones on the outside of the metallic atoms—the very valence electrons that take part in chemical combinations—which may even be considered as shared freely by all the atoms. Thus for our immediate purpose we may picture a metal as virtually a box, somewhat like an ordinary box which can hold things, nevertheless a particular kind of box which can hold "free" electrons.



Simple model of a metal

Let us examine more closely our crude model of a metal as a box. For simplicity of argument we shall consider a one-dimensional box, represented by the straight line AZ in the accompanying figure. By definition, then, within AZ free electrons are found; outside AZ there are none. Now physically what do we mean when we say

there are free electrons inside a metal box? To answer this we must bear in mind our modern concept of an electron as an elementary particle characterized fundamentally by its electric charge, its mass, and its so-called spin, and existing momentarily in a certain state of energy. Because of Heisenberg's uncertainty principle, of course, any precise specification of the energy state of an electron precludes the possibility of locating it exactly. All we can say *a priori* is that an electron may be here, there, or elsewhere in a given region (AZ). To predict specifically which place is more or less likely we need to know the function that satisfies a certain partial differential equation (Schrödinger's), which happens to be analogous to that of a vibrating string. The solutions of this equation have a wavelike character, and these so-called wave functions describing the state of an electron in the box are characterized by a set of parameters (quantum numbers) which are determined by the boundary conditions (at A and at Z). Each state of motion can be regarded as similar to that of a finite, uniform string with fixed ends; namely, a definite nodal pattern with varying amplitudes of vibration. The most remarkable feature of such motion is this restriction of allowable patterns, viz., that only certain wave functions with particular energy values are possible, in other words, only certain frequencies of vibration; in short, a discrete spectrum of wavelengths. Hence an electron in such a box may have any one of a group of energy values, called energy levels if ordered (usually so close together that they are said to be quasi-continuous), and may be any place in the box (the probability of a given position depends on the square of the wave function). Because of Pauli's exclusion principle, however, no more than one electron in a system can be regarded as being associated with the same wave function, although it so happens in this case of an electron gas that for each energy value there are actually two wave functions (said to be a state of spin degeneracy). Thus only two electrons may be regarded as having the same lowest energy value (in this instance not zero); two other electrons may be looked upon as occupying the next higher energy level; two others the next higher one; etc. Hence even at a temperature of absolute zero there are electrons that have energy about 100 times the average energy of a molecule of a gas under normal conditions of temperature and of pressure. Strange as this fact may seem in itself, it is less significant than one of its consequences, namely, that only the electrons with the highest energy values can have their energy increased by small amounts, inasmuch as such increments are not sufficient to raise electrons from the lower occupied levels to the vacant levels, which all have high energy values. It is for this very reason that comparatively few electrons share in the distribution of thermal energy and that, consequently, the electronic contribution to the specific heat of a metal at room temperature is small in comparison with that of the atomic residues.

For ordinary electric fields of force (measured by the voltage per centimeter), too, the possible increments of energy are so small that only those electrons in the higher energy levels are involved in the process of conduction. Upon collisions of these high-speed electrons with the atomic residues of the metal lattice the newly acquired kinetic energy of the electrons is transformed into random vibrational energy of the lattice, i.e., into thermal energy—a process which is commonly characterized as electrical resistance. The mean free path between collisions of these so-called conduction electrons with the atomic residues at room temperature turns out to be not the interatomic distance, but rather a distance 100 times greater. Of course, at absolute zero the mean free path would be infinite (cf. the electrical resistance of a pure metal is approximately proportional to its absolute temperature so that it would seem to extrapolate to zero at absolute zero—in other words, a metal would become a perfect conductor). These facts appear paradoxical until it is recalled that at absolute zero the atomic residues form a perfectly regular array; the resulting lattice is effectively a grating with its grating space several times smaller than the wavelength of the fastest electrons so that their

passage is practically undisturbed. To use a different analogy, the conduction electrons behave like a perfect fluid which adjusts its irrotational flow to conform to all the boundaries.

We now have a preview of electrical conduction, i.e., a theory based upon a simple model. Under normal conditions there are just as many electrons moving in any given direction in a metal as in the opposite direction; hence the net quantity of electricity passing through any plane is zero. Upon application of a field, however, those electrons having the highest energy values continuously acquire additional speed in the direction of the field, and in turn, continually lose these gains of kinetic energy upon collision with the atomic residues. Thus the original dynamic equilibrium is unbalanced and a net quantity of positive electricity is transferred in the direction of the field—this virtual electronic shift constitutes the electric current. The essential feature of this view is that comparatively few electrons are involved, whereas for the classical picture all the so-called free electrons were regarded as participating equally in the transfer of electric charge. In one respect, of course, the net result is the same; for the transfer of any quantity of electricity depends upon three factors, namely, the magnitude of each elementary charge, their number, and their speed. Although there are fewer electrons involved in the new picture, they are all moving so much faster that the electric current is approximately the same.

This heuristic picture of the process of electrical conduction does not contain an adequate concept of a conductor, perhaps, because the latter must be intimately linked up with the concept of an insulator. Accordingly we reconsider the usual differentiation of these two physical objects in terms of free electrons. Now in what sense are the valence electrons in our box-like conductor free? On the one hand, of course, they are completely free—free to move anywhere in the box. On the other hand, only the few conduction electrons are free—free to gain energy continuously from an applied electric field. The following analogy summarizes our concept of free electrons in a conductor. A valence electron in a conductor is as free as an actor who belongs to a certain company and who is privileged to play any role of the cast provided it is not being played by another member. Now then what about similar electrons in insulators?

As soon as we glance at a table of electrical conductivities (the measure of the amount of electric current conducted by a particularly shaped material of unit volume in a field of unit strength), we observe that some important factor must have been neglected in our simplified theory. For from our present viewpoint of the preferred position of the high-energy electrons we might be led to suppose that all metals would have the same electrical conductivity, whereas we intuitively feel that a metal should be a better conductor the more valence electrons it has. The experimental data do reveal valence dependence, but of the opposite tendency. For example, univalent sodium is a better conductor than divalent beryllium, which, in turn, is a better conductor than trivalent gallium. What we have overlooked is the attractive effect of the increase of the unbalanced positive charges on the atomic residues as the number of valence electrons increases. The atomic lattice evidently cannot be neglected!

For each individual atom itself may be considered effectively a small box that holds comparatively few electrons. Consequently it, too, has a certain discrete set of energy values, which may be regarded as associated with specific electronic orbits. Now if two such atoms are a great distance apart, the cloud of revolving electrons surrounding one nucleus shields its effect on the electrons about the other nucleus. On the contrary, if the outer electronic orbits of the two atoms overlap, the outer electrons of one atom are now influenced by the attraction of the nucleus of the other atom. In other words, the electric potential (measured by the work required to bring a distant positive unit charge to a point) in the region between the two atoms is lowered and electrons concentrate there (this condition is enhanced by the virtual attraction of two electrons with opposite

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spins). Thus the potential energy of the new configuration is lowered and the state is more stable; hence the atoms remain together as a molecule. Now a metal is merely a collection of such neighboring atoms, essentially a large molecule with atomic residues spaced at regular intervals and influencing the immediate electrons in proportion to the number of valence electrons. Thus our box-like metal may be thought of as containing a large number of smaller boxes arranged so as to give it an internal periodic structure. The motion of the electrons themselves in our one-dimensional model is evidently not so much like that of a uniform string with fixed ends, as we have previously supposed, but more like that of a row of similar beads connected by similar springs and fixed at the ends.

By way of orientation, therefore, let us review the analogous classical problem of a chain having N similar, equally spaced beads with similar springs as links, the end beads being fixed. In this case the possible energies for longitudinal vibrations form a discrete set of N values, but because of the dispersion of the elastic waves they are all confined within a narrow band, for which the highest frequency corresponds to a minimum wavelength equal to twice the minimum distance of separation of the beads. Even though overtones as such do exist, they are associated with the same band of energy values (actually, there is a periodicity in reciprocal wavelengths resulting from the periodicity of the bead spacing). Let us modify our problem so that the chain now consists of N massive beads alternating with N light ones. Then if each neighboring pair is roughly grouped as a single bead, the resulting motion will be similar to that in the preceding problem; there will be N discrete levels, both beads of a pair moving together. In addition, however, another band of higher-energy values exists; it corresponds to the higher-frequency motion in which the massive beads and the light beads move in opposite directions. It may be noted that the lattice vibrations of an alkali-halide crystal, which contains alternately positive and negative ions, are actually analogous to those of this second example. In this case, too, there are two motions of the oppositely charged ions: the acoustical branch with little phase difference and the optical branch with much phase difference. For the latter type of vibration there is a rapidly varying relative displacement of the charges and, consequently, electromagnetic radiation; it is this kind of motion (transverse, however) that is the mechanism of the infrared (so-called "restrahlen") absorption characteristic of the alkali halides.

In general, the vibration patterns for an electron in a solid are much more complex even than those of the above illustrations, but their distinctive feature is essentially the same, viz., distinct bands of discrete energy values with gaps occurring at electron wavelengths for which diffraction occurs. (The condition for diffraction, of course, depends upon the grating space.) Inasmuch as the interatomic distances vary in different directions, it may happen that the bands overlap in certain directions, i.e., a given range of energy values may be forbidden if the electrons travel in one direction, but allowed if they move in other directions.

On the basis of such band structures, we are now able to distinguish theoretically between a conductor and an insulator. We shall have need to bear in mind our previous observation that because of so-called spin degeneracy there can be two electrons (with opposite spins) associated with each energy value. Consider the univalent metal sodium. For N sodium atoms there are N valence electrons. Consequently the N energy levels of the conduction band (corresponding to the $3s$ energy level of a sodium atom) is only half full; the higher-energy levels of this band are vacant (in addition, there is an overlapping of bands). Therefore, the high-energy electrons of the metal can receive the relatively small increments of energy supplied by ordinary electric fields. Hence sodium is a conductor! The alkali-halide sodium chloride, on the other hand, is an insulator. Why? In this case there are $8N$ valence electrons for N molecules. One band (corresponding to the $2s$ atomic level of chlorine) is filled with $2N$ of these electrons and another one (corresponding to the $2p$ atomic levels of

chlorine) is filled with the remaining $6N$ electrons, whereas a third band (corresponding to the $3s$ level of the sodium atom) is entirely empty. Thus there is a gap between the uppermost filled band and the neighboring empty band so that no electrons can receive small increments of energy. On the other hand, consider the bivalent metal beryllium. In line with our argument for sodium we might expect the $2N$ valence electrons here to fill the conduction band and thus to fulfill the condition for an insulator. Beryllium, on the contrary, is a conductor. What happens is that the overlapping of the bands in different directions causes a resultant band that is only partially full, allowing some of the electrons to receive small increments of energy. The vacant energy levels, however, are not so plentiful as in the case of sodium so that fewer electrons are able to participate in the conduction process; hence the electrical conductivity of beryllium is less than that of sodium.

In summarizing the answers to our two review questions we note first that valence electrons are just as free to move throughout an entire insulator as they are throughout a conductor. The essential difference, however, is that in a conductor some of these electrons are free to receive small increments of energy whereas in an insulator none are able to do so. Completing our previous analogy we remark that in an insulator there are just as many roles as actors whereas in a conductor there are more roles than actors.

We return now to our primary question, viz., how is it possible for an insulator to become a conductor. The answer would seem to be straightforward: the increment of energy must be sufficiently great to allow a high-energy electron to jump from its own band, which is full, to the next higher band, which is empty. This presumably could be accomplished by a great increase in temperature—only the solid would melt before that temperature could be attained. It could undoubtedly be made possible also by a very strong electric field—only an insulator actually breaks down for fields smaller than those that would be expected theoretically. Evidently there is some latent mechanism that accounts for electric breakdown.

It is not unreasonable to seek a clue in the phenomenon of electric breakdown of a gas. When the voltage applied across a gas is slightly less than that required to produce breakdown, free electrons are able to gain sufficient energy over several mean free paths to knock out other electrons upon collision with atoms (ionization by collision). Presumably these latter electrons would be able to free still other electrons, etc. Nevertheless, breakdown does not take place. Why? Can there be some continual loss of energy analogous to friction in mechanics? Indeed, there does exist such a process, the so-called excitation of a molecule, in which an electron is removed only to an outer orbit instead of infinitely far away, as in the case of ionization. Such an electron, however, soon returns to its initial orbit either by radiating, or by increasing the kinetic energy of a colliding molecule (so-called collision of the second kind); in either case its excess potential energy is irretrievably lost. This excitation process is initiated neither by very slow electrons, which do not have sufficient energy; nor by very fast electrons, which do not have sufficient time. For some intermediate speed, however, the probability of excitation, and consequently, of the loss of energy, is a maximum. This speed, then, is the one at which breakdown occurs. Any electron having a slightly greater speed will have a net gain of energy, so that it can continuously acquire sufficient energy to produce ionization instead of mere excitation. In this manner other electrons are freed. These, in turn, are accelerated, they ionize other molecules and free more electrons—thus an avalanche soon results! It is tempting to consider this same mechanism of electronic excitation as effective also in a solid—but without success, inasmuch as the lowering of the atomic ionization potential by the atomic residues in a solid causes it to be not appreciably different from the excitation potential.

On the other hand, the excitation of lattice vibrations does afford an analogous frictional mechanism for electrons acci-

dentally present in every insulator. Here, too, very slow electrons have insufficient energy for excitation and fast ones have insufficient time. Only moderately fast electrons have a significant probability of exciting these vibrations. Again we have a maximum space rate of energy loss. It has been suggested by von Hippel (*1*) that the applied electric field required for an equal space rate of energy gain may be taken as the criterion for electric breakdown; for, an electron in a slightly greater field will experience a net gain of energy and thus eventually acquire sufficient energy to produce ionization. Thus other electrons will be freed, accelerated, etc., until an avalanche of such free electrons is formed, i.e., breakdown occurs. Let us examine this process more closely.

Consider the behavior of a low-speed electron as it passes a positively charged atomic residue in a lattice (the ion may be considered effectively free if the time of passage is much less than the period of a lattice vibration). Along the path of motion (assumed to be linear as a first approximation) there is a component of the force of attraction, which first speeds up the electron and then slows it down so that the net effect is null. At right angles to the path, however, the component of the force of attraction acts always in the same direction and thus produces an increment of impulse. The increased kinetic energy given to the atomic residue can be calculated from a knowledge of the force acting and of the time of passage. Now the force we are concerned with in the dielectric medium must not be computed from the so-called static dielectric constant, which includes the influence of the electric polarization due to distortion within an atomic residue, as well as the effect of the relative displacement of the residue as a whole. The dielectric constant for a high-frequency electric field (e.g., light), on the other hand, is due solely to such electronic distortions inasmuch as the more massive ions do not have time to get under way. Evidently the difference between these two effects measures the force responsible for the ionic displacement alone. Using this value, then, we can calculate the increment of energy received by a single ion per unit length of path. What remains to be done is to sum such increments for all ions influenced by the passing electron. Of course, the very distant ions need not be included inasmuch as the time of passage for them is of the same order of magnitude as the time of a lattice vibration so that the ions are no longer approximately free; instead they follow adiabatically the electron motion. The very near ions, too, are omitted in this classical calculation since it becomes invalid when distances are of the order of the wavelength of an electron. (It should be mentioned, however, that the problem can be formulated just as well completely in quantum mechanical terms, but this evaluation, in turn, involves an approximation that also lacks rigorous justification.) Thus the space rate of energy loss can be determined as a function of electronic velocity; its maximum can be ascertained. It is this maximum space rate of energy loss that must be set equal to the applied electric field for a quantitative expression of von Hippel's criterion for electric breakdown.

Calculations have been made in this manner by Teller and myself (*2*) for the alkali halides; the results are in essential agreement with observations. More recently Attwood and Bixby (*3*) have applied our theoretical expression to data for carbon tetrachloride and have found agreement here, too, although the formula was not derived originally for such a substance. It should be noted also that a formula obtained by Fröhlich (*4*) is equally satisfactory. Fröhlich, too, utilizes von Hippel's frictional mechanism, but he introduces a distinctly different breakdown criterion namely, a field in which acceleration is continuously possible for all electrons having energy sufficient for ionization. The distinctive feature of his picture is that it requires very fast electrons for initiating the breakdown process, whereas our theory starts with comparatively slow electrons. As yet, no decisive experiment has been made to test these hypotheses. Still one other criterion should be mentioned. In an informal communication Seitz (*5*) has suggested

that breakdown occurs when an electron can produce a secondary electron over a path length determined by the number of electrons needed to comprise an avalanche. The consequences of this hypothesis are at present only in a qualitative form.

In searching for an answer to the question, how is it possible for an insulator to become a conductor, we have found clues to the phenomenon of electric breakdown. Our understanding, however, must remain only partial until we can account for the dependence of breakdown upon various physical factors such as temperature and trapping.

Buehl and von Hippel (*6*) have found that the electric breakdown for potassium bromide is 25 per cent less at 200° absolute than at 300° absolute. Moreover, the breakdown field increases steadily with increase of temperature up to 50° Centigrade after which it decreases monotonically. Now the frictional mechanism, it is true, yields a temperature dependence in that according to Planck's partition law the vibrational energy is a function of temperature. This theoretical prediction, however, gives a less rapid increase than that observed and allows for no decrease at all. At present, there is no completely satisfactory explanation of the actual variation with temperature; perhaps, because it is closely related to the other important factor, namely, the possibility of capture to the free electrons involved. Let us turn our attention to this so-called phenomenon of trapping.

In alkali-halide crystals there exist various defects in the ionic lattice. For example, there are vacant places owing to the shifting of some ions to interstitial positions and owing to migration of others to the surface. (In either case the vacated regions may be occupied by neighboring ions, thus making ionic conduction possible.) Now a negative-ion vacancy in an electrically balanced lattice is effectively a positive charge; thus it behaves like an empty box that can hold free electrons. Thus associated with such a vacancy are discrete energy levels, which happen to be just below the conduction band. Experimental evidence of trapping of electrons in such vacancies in alkali-halide crystals is found in the existence of ultraviolet absorption peaks, which are related to the raising of electrons from such discrete energy levels to the conduction band. Furthermore, certain varieties of these crystals have characteristic colors, e.g., yellow for sodium chloride, signifying the comparatively small energy change involved in any absorption of visible light so that the existence of so-called F-centers (Farbenzentren, color centers) has been long postulated by Pohl.

Suppose more than half the free electrons having sufficient energy for ionization are captured by such vacancies in a crystal. Then an avalanche can never result; breakdown cannot occur! It is important, therefore, to calculate the probability of capture of an electron by various processes. This problem, however, presents considerable mathematical difficulties. An initial step has been made by Meyer (*7*), who has investigated trapping by a negative-ion vacancy. We shall illustrate his method for a one-dimensional problem.

Consider an electron moving in a straight line under the influence of an applied electric field and a capture center. There are four special cases depending upon the initial direction of motion of the electron relative to the capture center and to the applied field. Let us consider specifically an electron moving away from a capture center in the direction of the applied field. The attracting force of the capture center can be approximated by the field of force of a hydrogen-like ion in a dielectric (this procedure is sufficiently accurate at least for the outer electron orbits). Owing to the lattice vibrations, as we have just seen, there is a "frictional" force, too; it can be shown to be proportional to $(ln\ v^2)/v^2$ (v is the speed). The problem, then, is to determine the minimum distance from the capture center for an electron with a given initial speed to escape to infinity. Inasmuch as numerical integration of the equation of motion is required in each instance, it is more convenient to formulate the problem in terms of a finite path of motion.

Consider that critical point where the

applied field is just balanced by the opposing field of the capture center. If the electron can reach this point with slightly greater than zero speed, it will henceforth be effectively under the influence of the applied field and will accordingly escape to infinity. The problem, therefore, may now be restated as finding the minimum speed an electron must have at any given distance in order for it to arrive at the critical point with zero speed. Unfortunately this procedure, too, involves considerable numerical work, which, in turn, can be reduced by the following computational scheme. Suppose the electron is initially at rest at the critical point. Allow it to move toward the capture center with a reversed frictional force. Its speed at each point can then be calculated. If the direction of motion at any point is now reversed, the electron will just reach the critical point. For slightly higher speed the electron will escape. If the actual speed of an electron at a given point is smaller than this calculated critical value, the electron will not escape. In other words, if an electron is actually closer to the capture center than the point for which its given speed is equal to the critical value, it will remain captured. In this manner the cross-sectional radius of capture for various speeds of an electron has been estimated for the four possible initial conditions relative to the capture center. The calculations have been carried out in the case of sodium chloride for several applied fields of the order of magnitude of those occurring in breakdown.

The effect of trapping in sodium chloride can then be estimated on the basis of the above calculations. It is found that if there are $(10)^{18}$ capture centers per cubic centimeter, less than half of the free electrons will be trapped so that an avalanche will result. On the other hand, if there are three times as many such centers, half of the electrons will be captured before they reach 13 per cent of the velocity needed for ionization so that the breakdown phenomenon cannot occur. Somewhere in between these two values for the number of capture centers the effect of trapping becomes significant. Now alkali-halide crystals usually have only $(10)^{14}$ to $(10)^{15}$ capture centers per cubic centimeter (the number is greater in the case of single crystals). Hence the influence of trapping should become important for alkali-halide crystals only if they are prepared specially so as to have a greater density of capture centers.

Thus our theoretical understanding of the phenomenon of electric breakdown is contingent upon further experimental knowledge of the controlling factors.

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PHYSICS.—*Forces between linear circuits according to O'Rahilly.*[1] FRANK WENNER, Department of Terrestrial Magnetism, Carnegie Institution of Washington.

Forces between linear circuits (that is, coils of insulating wire with currents in them) have beeen investigated from time to time during the past more than 100 years. Of the workers in this field mention may be made of Ampere, Weber, Maxwell, Webster, Peirce, Mason and Weaver, Gray, Curtis, Helmholtz, Page and Adams, and Cullwick. In addition, many others have had something to say on the subject.

These investigations have led to a particular way of looking at the situation, namely: that each element of any one circuit acts directly on each element of the one or more other circuits and that what we observe is the sum of such actions. It is customary therefore to state the effects observed by means of formulae which frequently are presumed to be statements of laws of actions between elements of circuits.

One of such formulae usually arrived at on an analysis of the actions of two closed circuits on each other may be written as follows:

$$d^2F = PI_1I_2(3\cos\phi_1\cos\phi_2 - 2\cos\gamma)ds_1ds_2/r^2. \quad (1)$$

Here P represents the effective permeability of the ambient space (most writers omit a symbol for the permeability and state that the formula applies in a vacuum or in air); I_1 represents the current in one of the circuits; and I_2 represents the current in the other circuit.

Referring to Fig. 1, ds_1 and ds_2 represent elements of the lengths of the two conductors; r represents the distance between ds_1 and ds_2; ϕ_1 represents the angle between r and ds_1; ϕ_2 represents the angle between r and ds_2; γ represents the angle between ds_1 and ds_2. In general ds_1 and ds_2 are not coplanar. Also, d^2F represents the component of the force acting on ds_1 and ds_2 in the direction of the line joining them.

It is to be understood that the symbols d^2F, P, I_1, I_2, ds_1, ds_2, and r represent physical quantities, not merely numbers of units of physical quantities, while ϕ_1, ϕ_2 and γ represent numerics, that is, numbers.

Of other similar formulae those more commonly used are

$$d^2F = PI_1I_2\cos\gamma ds_1ds_2/r^2 \quad (2)$$

and

$$d^2F = PI_1I_2\cos\phi_1\cos\phi_2 ds_1ds_2/r^2. \quad (3)$$

Now O'Rahilly states that the correct formula is[2]

$$\overline{d^2F} = I_1I_2\overline{ds_1}x(\overline{ds_2}x\overline{r})/r^3 \quad (4)$$

where $\overline{d^2F}$ $\overline{ds_1}$ $\overline{ds_2}$ and $\overline{r}$ represent vectors. If formula (4) is written in such a way that we may attribute to the symbols the significances stated above it becomes

$$d^2F = PI_1I_2\sin\phi_1\sin\phi_2 ds_1ds_2/r^2. \quad (5)$$

In case W represents the mutual potential energy of the two circuits and the ambient space it follows from formulae (1), (2), (3), and (5) that

$$d^3W = PI_1I_2(3\cos\phi_1\cos\phi_2 - 2\cos\gamma)ds_1ds_2dr/r^2 \quad (6)$$

$$d^3W = PI_1I_2\cos\gamma ds_1ds_2dr/r^2 \quad (7)$$

$$d^3W = PI_1I_2\cos\phi_1\cos\phi_2 ds_1ds_2dr/r^2 \quad (8)$$

$$d^3W = PI_1I_2\sin\phi_1\sin\phi_2 ds_1ds_2dr/r^2. \quad (9)$$

Now let it be assumed that ds_1 or ds_2 is moved, without rotation, in the direction of the line joining them, from the distance r to infinity. Then there would be involved the

$$\int_r^\infty dr/r^2 = 1/r. \quad (10)$$

Obviously therefore formulae (1), (2), (3) and (5) lead to the following expressions for the mutual potential energy of two circuits, namely:

[1] Paper presented in part at the March 30, 1946, meeting of the Philosophical Society of Washington. Received May 15, 1946.

[2] O'RAHILLY, ALFRED, *Electromagnetics—a discussion of fundamentals:* 519. 1938.

$$W = PI_1I_2 \oint\oint (3\cos\phi_1\cos\phi_2 - 2\cos\gamma)ds_1ds_2/r \quad (11)$$

$$W = PI_1I_2 \oint\oint \cos\gamma ds_1ds_2/r \quad (12)$$

$$W = PI_1I_2 \oint\oint \cos\phi_1\cos\phi_2 ds_1ds_2/r \quad (13)$$

$$W = PI_1I_2 \oint\oint \sin\phi_1\sin\phi_2 ds_1ds_2/r. \quad (14)$$

Of these expressions for the mutual potential energy of two circuits that given by formula (12) and generally attributed to Neumann has been used more than any other. That given by formula (13) will be found to work out best in case of a helix and a concentric circle in the plane of the end of the helix.

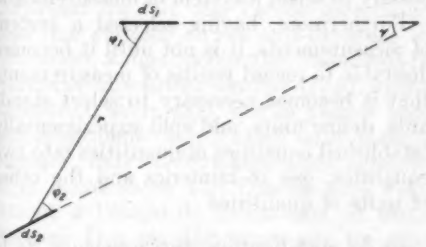

FIG. 1.—Diagram showing the geometry involved in formulae purporting to be statements of laws of force actions between elements of two linear circuits, in the special case in which ds_1 and ds_2 are coplanar. (DTM #7864.)

Formulae (11), (12), and (13) become identical on integrating around either circuit and on a second integration, that is, around the other circuit, give a result generally considered to be correct.

Formula (14) leads to the conclusion that there is no mutual potential energy associated with two adjacent circuits and consequently no force acting between adjacent coils of insulated wire in each of which there is a current. Thus, taking what O'Rahilly insists is the correct formula at its face value we are led by what apparently are proper steps to a conclusion contrary to what we find by experiment. However, it should be pointed out that his formula (4) may be juggled in such a way as to give a result in conformity with the result obtained by the use of either of the formulae (1), (2), or (3).

With reference to these force formulae, namely (1), (2), (3), (4), and (5), it is hardly appropriate to say that any one is correct or incorrect. No one has been proved or disproved by direct experiment. Except to the extent that (4) and (5) are equivalent, each is in definite conflict with every other. When applied to actual circuits formulae (1), (2), and (3) lead directly and (4) indirectly to the same result. Consequently no one of them should be considered to be a statement of a law of physics. They are merely postulates or working hypotheses which should be judged entirely on the basis of their usefulness in applied physics.

Here this matter has been discussed in such a way as to make the conclusions reached and those which may be reached independent of units. As illustrations consider the application of force formula (3) to a particular pair of circuits. Then if conditions are more or less ideal and if C is considered to represent the length $\oint\oint \cos\phi_1\cos\phi_2\, ds_1ds_2/r$, it follows that—

(1) The mutual potential energy of the system

$$W \text{ is } PI_1I_2C. \quad (15)$$

(2) The component in the direction x of the force, acting between the coils,

$$F_x \text{ is } PI_1I_2dC/dx. \quad (16)$$

(3) The effective permeability of the ambient space

$$P \text{ is } W/I_1I_2C. \quad (17)$$

(4) The product of the two currents

$$I_1I_2 \text{ is } F_x/PdC/dx. \quad (18)$$

(5) The mutual inductance of two coils and the ambient medium

$$M \text{ is } PC. \quad (19)$$

If formula (3) is combined with the experimentally established law for induced electromotive force and with Ohm's law it follows that a resistance

$$R \text{ is } PC/T \quad (20)$$

where T is the effective period of a recurring action in a mechanism which in one respect behaves like a resistor. (A Lorenz apparatus is one of several types of mechanism which in effect produce a potential drop or electromotive force proportional to an impressed current and consequently has associated with it a resistance.)

If R' is the resistance associated with a standard resistor and if by measurement it is found that $R' = AR$ it follows that

$$R' = APC/T. \tag{21}$$

It also follows that

$$P = R'T/AC. \tag{22}$$

As to the significances of formulae (15) to (22) inclusive, all of which involve force formula (3), it should suffice to point out—

(a) That formula (20) serves to define resistance as a quantity of the electromagnetic system of measurements.

(b) That formula (21) serves in the measurement of the resistance associated with a standard resistor in terms of standards of length, time and permeability, and

(c) That formula (22) serves in a measurement of the effective permeability associated with an ambient space in terms of standards of resistance, time and length—that is, in the measurement of permeability as a quantity of the international system of measurements.

Possibly it should be explained that *as presently used* in applied physics—

(a) The electromagnetic system of measurements involves the use of length, mass, time and permeability as basic quantities and the definition of all units of the system in terms of standards of these 4 quantities.

(b) The international system of measurements involves the use of length, time, electromotive force and resistance as basic quantities and the definition of all units of the system in terms of standards of these four quantities.

It may be noted that it is not until a need for a law of physics, whether hypothetical as are the force laws considered here or experimentally established as is Ohm's law, has arisen does it become necessary to select a system of measurements.

Furthermore, having selected a system of measurements, it is not until it becomes desirable to record results of measurements that it becomes necessary to select standards, define units, and split experimentally established equalities of quantities into two equalities, one of numerics and the other of units of quantities.

BIOCHEMISTRY.—*Faits expérimentaux sur la stabilisation anti-oxygénée de la bilirubine par les protéines plasmatiques et hypothèse sur la nature de la cénapse albumino-bilirubinique du plasma.*[1] G. BARAC, et R. ROSEMAN (Baltimore, Md.)[2], Institut de Clinique et de Policlinique Médicales, Université de Liége, Belgique (Directeur: Prof. Dr. L. Brull). (Communicated by JAMES I. HOFFMAN.)

INTRODUCTION

Les recherches de l'un de nous sur le mécanisme de l'élimination rénale de la bilirubine l'ont amené à étudier l'état physico-chimique du pigment dans le plasma, après qu'il eut constaté que la bilirubinémie totale n'est pas le seul facteur qui règle la bilirubinurie (*2*). D'ailleurs, l'importance de l'état physico-chimique des constituants plasmatiques, au point de vue de leur élimination rénale, a été démontrée, dans cet Institut, par Brull, dans un travail fondamental en 1930 (*3*). En ce qui concerne la bilirubine, s'il est actuellement établi (*10, 13, 14*) que, dans le plasma, elle est liée à l'albumine, il n'existe, par contre, à notre connaissance, aucun fait expérimental permettant une hypothèse concernant l'endroit de la molécule bilirubinique où cette liaison s'effectue.

[1] Received March 1, 1946.

[2] Nous exprimons notre vive gratitude à Monsieur le Professeur E. J. Cohn, Department of Physical Chemistry, Harvard Medical School, et à Monsieur le Professeur H. Neurath, Department of Biochemistry, Duke University School of Medicine, qui ont eu la grande amabilité de mettre à notre disposition les cinq fractions de protéines plasmatiques et les albumines cristallisées, utilisées au cours de nos recherches.

Et cependant, la connaissance de cet endroit serait d'une grande importance, au point de vue du mécanisme biochimique de la bilirubinurie. En effet, comme la bilirubinurie ne s'accompagne généralement pas d'albuminurie, il en résulte que: (1) la bilirubine doit être séparée de sa cénapse avant son apparition dans l'urine; (2) suivant l'endroit de la molécule bilirubinique où sa liaison avec l'albumine est réalisée, ainsi que d'après la nature de cette dernière, la séparation du pigment reconnaîtra forcément des mécanismes biochimiques différents. En effet, si, par exemple, la bilirubine est combinée à l'albumine par les fonctions carboxyles du pigment, si, en d'autres mots, il s'agit d'un bilirubinate d'albumine, la scission se fera suivant un tout autre processus que si cette liaison a lieu au niveau d'une autre fonction et par un moyen différent.

Partant du fait que l'acide ascorbique ainsi que certains autres anti-oxygènes et réducteurs, à micro-molécules, stabilisent la bilirubine en solution alcaline (*1*, *3*), ayant constaté, d'autre part, que le plasma normal, additionné de bilirubine ou le plasma ictérique, tous les deux alcalinisés, agissent de la même façon (*4*), l'un de nous s'est attaché à l'étude du mécanisme de cette réaction. Il a pu démontrer que les protéines plasmatiques totales délipidées et, dans une certaine mesure, une préparation d'albumine plasmatique, non purifiée, sont actives, cependant que divers lipides, examinés isolément, ainsi que l'ensemble des lipides plasmatiques chloroformo-solubles sont sans effet. La conclusion de ces recherches fut que la stabilisation anti-oxygénée de la bilirubine dans le plasma était due très vraisemblablement aux protéines, voire surtout à l'albumine. Et comme la différence chimique entre la bilirubine et sa forme oxydée la biliverdine se caractérise par la transformation du groupe méthane, reliant les deux noyaux pyroliques du milieu, en méthine, il était à supposer que, dans le plasma, c'est en cet endroit de la molécule bilirubinique que l'albumine agit comme anti-oxygène par sa liaison avec le pigment. Suivant cette interprétation, l'orientation de la molécule bilirubinique était telle que ses fonctions carboxyles étaient dirigées vers la phase aqueuse du milieu. Cette explication, toute provisoire, demandait de nouvelles expériences, notamment au moyen de protéines plasmatiques plus individualisées.

Grâce à l'aide bienveillante du Laboratoire de Chimie Physique de l'Université Harvard et à celle du Laboratoire de Biochimie de l'Université Duke, qui ont bien voulu mettre à notre disposition une série de protéines plasmatiques, nous avons pu entreprendre ces recherches. Les résultats obtenus jusqu'à présent constituent la première réalisation de notre programme dans ce domaine et forment une partie des données de ce travail.

OBJET DU TRAVAIL

(1) L'albumine plasmatique est-elle réallement anti-oxygène vis-à-vis de la bilirubine?

(2) Peut-on obtenir cet effet stabilisateur avec n'importe quelle protéine plasmatique?

(3) Peut-on obtenir un résultat analogue avec l'un des acides aminés constituant la molécule albuminique ou avec le mélange de tous les acides aminés de cette molécule, à la concentration de l'albumine plasmatique habituelle, ou bien s'agit-il d'une propriété de la molécule albuminique, considérée comme telle?

(4) La propriété anti-oxygène du plasma se manifeste-t-elle, dans les mêmes conditions, également vis-à-vis d'autres molécules facilement oxydables tels certains polyphénols?

TECHNIQUE DES MESURES

Nous utilisons comme méthode d'analyse la photométrie directe du pigment et comme appareil le photomètre graduel de Pulfrich. Nous nous servons du filtre S_{43}, auquel correspond le maximum d'absorption du pigment dans ces conditions, ainsi que l'un de nous l'a établi précédemment au moyen de cet appareil (*1*) et confirmé ses résultats avec A. Lambrechts, en utilisant la méthode spectrophotométrique visible (*11*).

RÉSULTATS EXPÉRIMENTAUX

Vitesse d'oxydation de la bilirubine en solution alcaline pure.—7,5 mgr. de bili-

rubine Hoffmann-LaRoche, identique à celle de Fischer, d'après Heilmeyer, sont dissous dans un litre de NaOH N/100. La solution est conservée au laboratoire, à la lumière ordinaire, au contact de l'air. Elle est suivie périodiquement au photomètre. La Fig. 1 montre que le maximum de la transformation subie par la bilirubine a lieu pendant les 7 premières heures et que dans la suite elle se ralentit considérablement.

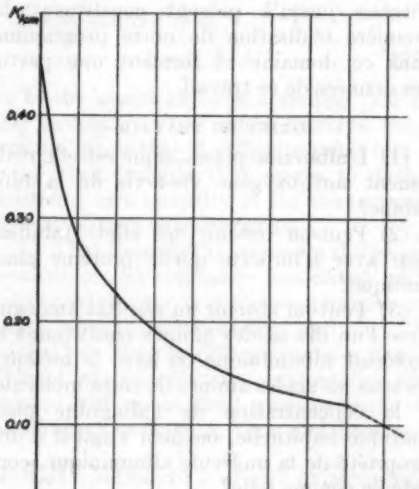

FIG. 1.—Vitesse d'oxydation de la bilirubine en solution alcaline pure.

Protéines et stabilisation anti-oxygénée de la bilirubine en milieu alcalin. Essais avec les solutions d'albumine Cutter et de globuline Lilly.—En partant d'une solution d'albumine Cutter, utilisée pour transfusion, et d'une solution de globuline Lilly, nous préparons, par dilution, au moyen de NaOH N/100, des solutions ayant respectivement 90 et 84 gr. de protéines p. 1000. A chacune nous ajoutons de la soude solide jusqu'à obtention d'un pH de 10, vérifié au moyen du papier indicateur Merck. Chaque solution est alors partagée en deux parties. A l'une nous ajoutons un volume égal de soude centinormale. Elle servira de témoin. A l'autre, nous ajoutons un volume égal d'une solution fraîchement préparée de bilirubine à 15 mgr. p. 1000 de NaOH N/100. Chacune des solutions bilirubiniques est photométrée périodiquement avec son témoin correspondant, la différence des valeurs enregistrées correspondant à la bilirubine seule. Le Tableau 1 contient les résultats obtenus. On voit que dans la solution albuminique la bilirubine reste stable au moins pendant 73 heures, et que dans la solution de globuline la stabilité du pigment dure 3 heures.

Essais avec les diverses fractions de protéines plasmatiques "Harvard."—2 gr. de chaque fraction (*9*) sont additionnés progressivement de NaOH N/100 jusqu'à obtention d'un volume de 25 cc. On agite au moyen d'une baguette en verre pour obtenir une dissolution complète. Comme ci-dessus, nous ajoutons de la soude solide pour obtenir un pH de 10. La moitié du volume de chaque solution est additionnée d'un volume égal de NaOH N/100 et sert de témoin, à l'autre moitié on ajoute un même volume de bilirubine à 15 mgr. p. 1000 dans NaOH N/100. Les examens ont lieu comme ci-dessus. Les résultats figurent au Tableau 1. On voit que seule la fraction V, comprenant 100 p. 100 d'albumine, est nettement active puisqu'elle stabilise la bilirubine au moins pendant 30 heures.

Essais avec deux albumines plasmatiques cristallisées "Duke."—Nous avons réalisé des essais avec deux albumines plasmatiques cristallisées, l'une humaine, l'autre bovine. La préparation des solutions bilirubiniques et témoins est la même que ci-dessus, la concentration en albumines étant de 40 gr. p. 1000. Nous donnons dans le Tableau 1 les résultats obtenus. Ceux-ci montrent que dans ces milieux la bilirubine est stable au moins pendant 7 heures et que dans la suite il y a une légère diminution de cette stabilité.

Acides aminés et stabilisation anti-oxygénée de la bilirubine en milieu alcalin. Action des acides aminés examinés isolément.—La molécule d'albumine plasmatique comprend 13 acides aminés. En suivant les données de Lehnartz (*12*), nous avons utilisé pour chaque acide aminé sa concentration albumino-plasmatique correspondant à 45 gr. d'albumine par litre.

TABLEAU 1

Solutions protéiques additionnées de Bilirubine	K_1 cm. Init.	K_1 cm. après 1 H.	K_1 cm. après 2 H.	K_1 cm. après 3 H.	K_1 cm. après 4 H.	K_1 cm. après 5 H.	K_1 cm. après 6 H.	K_1 cm. après 7 H.	K_1 cm. après 8 H.	K_1 cm. après 9 H.	K_1 cm. après 10 H.	K_1 cm. après 24 H.	K_1 cm. après 30 H.	K_1 cm. après 48 H.	K_1 cm. après 73 H.
Cutter	0.45	0.46	0.43		0.45		0.43		0.43		0.45	0.45	0.45	0.43	0.43
Lilly	0.48	0.48		0.45		0.44	0.42	0.40	0.41			0.35			
Protéines Harvard															
Fract. I	0.42	0.30	0.26	0.25		0.19	0.17								
Fract. II	0.41	0.31		0.24	0.20	0.22		0.21		0.19					
Fract. III	Insoluble														
Fract. IV	0.46	0.40		0.30		0.28									
Fract. V	0.42	0.43		0.42		0.42		0.41		0.41	0.40	0.40	0.42	0.38	0.35
Albumines cristallisées Duke															
Humaine	0.51	0.50			0.50		0.50	0.49	0.47	0.45		0.44	0.45		
Bovine	0.48	0.46			0.46		0.46	0.46	0.46	0.41		0.42	0.42		

Les valeurs de K (coefficient d'extinction) de ce Tableau représentent la différence des coefficients d'extinction des solutions bilirubiniques et de leurs témoins correspondants.

TABLEAU 2

Solution d'ac. aminé +Bilirubine	K_1 cm. In.	K_1 cm. après 30'	K_1 cm. après 1 H.	K_1 cm. après 2 H.	K_1 cm. après 3 H.	K_1 cm. après 5 H.	K_1 cm. après 8 H.	Remarques
Alanine	0.60	0.58	0.53	0.49	0.45	0.36	0.33	
Leucine	0.16	0.17	0.14					Verdissement rapide de la solution dès l'addition de la solution de bilirubine.
Ac. glutamique	0.58	0.53	0.50	0.46	0.42	0.33		
Ac. aspartique	0.17	0.15	0.12					Même remarque.
Sérine d.l.	0.37	0.24	0.18		0.04			Même remarque.
Cystine l.	0.48	0.39	0.33	0.27	0.25	0.22	0.21	
Lysine l.	0.32	0.20	0.19		0.12			Même remarque.
Arginine d.	0.51	0.42	0.37		0.28	0.22	0.15	
Phénylal. d.l.	0.21	0.12	0.09		0.07			Même remarque.
Tyrosine	0.53	0.53	0.50	0.45	0.40			
Proline l.	0.51	0.46	0.43		0.32	0.29	0.20	
Histidine	0.55	0.55	0.52	0.47	0.40			
Tryptophane l.	0.49	0.41	0.38		0.29	0.25	0.21	
Mélange des 13 ac. aminés +Bilirubine	0.47	0.33	0.25	0.20	0.18	0.16	0.12	

TABLEAU 3

Filtre S.	K_1 cm. Sol. aq. alc. de Hydroq.	K_1 cm. Sol. aq. alc. de Pyrog.	K_1 cm. Sol. aq. alc. de Adrén.	$K_{8,5}$ cm. Plasma I alc. tel quel	$K_{0,5}$ cm. Plasma I alc.+ Hydroq.	$K_{0,5}$ cm. Plasma II alc. tel quel	$K_{0,5}$ cm. Plasma II alc.+ Pyrog.	$K_{0,5}$ cm. Plasma II alc.+ Adrén. Init.	$K_{8,5}$ cm. Plasma II alc.+ Adrén. après 8 H.
43	0.23	1.00	0.14	0.43	0.60	0.27	0.72	0.32	0.61
47	0.19	0.62	0.07	0.38	0.56	0.26	0.61	0.29	0.40
50	0.15	0.36	0.02	0.31	0.46	0.18	0.45	0.18	0.25
53	0.09	0.25	0.01	0.26	0.37	0.07	0.28	0.04	0.09
57	0.03	0.14	0	0.14	0.33	0.03	0.16	0.02	0.04
61	0	0.10	0	0.13	0.25	0.02	0.11	0	0.02
66.6	0	0.03	0	0.11	0.17	0	0.05	0	0
72	0	0	0	0.08	0.09	0	0	0	0
75	0	0	0	0.09	0.09	0	0	0	0

La quantité de chaque acide aminé correspondant à 100 cc. de solution est neutralisée par de la soude à 10 pour-cent puis ajoutée de NaOH N/100 jusqu'à 50 cc et de 50 cc de bilirubine à 15 mgr. p. 1000 de NaOH N/100. Le Tableau 2 donne les résultats obtenus. Ceux-ci indiquent que pas un seul acide aminé ou plus exactement pas un seul dérivé sodique correspondant n'est anti-oxygène vis-à-vis de la bilirubine.

Action du mélange de ces 13 acides aminés.—Dans cette expérience nous procédons comme ci-dessus, en opérant sur le mélange de ces 13 acides aminés. Le Tableau 2 contient les résultats obtenus. On voit que dans ce milieu la bilirubine s'oxyde pratiquement avec la même vitesse qu'en solution alcaline pure.

Cas particulier de la cystéine.—Les solutions sont préparées d'après le procédé ci-dessus en utilisant les concentrations suivantes de chlorhydrate de cystéine: 470, 235, 100, 50, 25, mgr. pour-cent. Les résultats obtenus montrent qu'à partir de la concentration de 100 mgr. p. 100, la cystéine est nettement active. Toutefois, à concentration égale, son activité est moindre que celle de l'acide ascorbique.

Essais sur la stabilisation anti-oxygénée de quelques polyphénols facilement oxydables dans le plasma alcalinisé.—Nous avons opéré sur les polyphénols suivants: hydroquinone, pyrogallol, adrénaline. Comme on sait, ces polyphénols s'oxydent en solution alcaline en dérivés colorés.

Absorption visible des dérivés colorés de ces polyphénols en solution alcaline pure.—20 mgr. de chaque polyphénol p. 1000 de solution, sont dissous dans de la soude N/100. Les couleurs développées instantanément sont analysées immédiatement au photomètre.

Absorption visible des dérivés colorés de ces polyphénols dans le plasma alcalinisé.—Deux plasmas humains frais, citratés au dixième, sont alcalinisés à pH 10, au moyen de soude solide. A 10 cc du premier plasma on ajoute 7 mgr. d'hydroquinone. Le deuxième plasma est partagé en trois échantillons. A deux d'entre eux on ajoute respectivement 5 mgr. de pyrogallol et la même quantité d'adrénaline, le troisième servant de témoin. A l'exception du plasma additionné d'adrénaline où la coloration se développe lentement, les deux autres plasmas additionnés d'hydroquinone et de pyrogallol changent très rapidement de couleur. Le Tableau 3 réunit les résultats obtenus pour ces polyphénols en solution aqueuse alcaline ainsi que dans les plasmas alcalinisés de même que l'absorption de ces derniers avant l'addition de ces substances. On voit, d'après ces résultats, que le plasma alcalinisé n'est pas antixoygène vis-à-vis de l'hydroquinone et du pyrogallol, mais que, par contre, il empêche l'oxydation de l'adrénaline pendant une certaine durée (*6*, *7*).

DISCUSSION

Les résultats expérimentaux décrits dans ce travail montrent tout d'abord que l'oxydation de la bilirubine en milieu alcalin est considérablement retardée par l'albumine plasmatique, confirmant ainsi l'hypothèse de l'un de nous sur le rôle de cette protéine dans l'effet anti-oxygène du plasma vis-à-vis de ce pigment. En effet, nous avons obtenu ces résultats non seulement avec la solution d'albumine Cutter, mais également avec la fraction V Harvard, ainsi qu'avec deux albumines plasmatiques cristallisées, l'une humaine, l'autre bovine. Ils montrent, de plus, que la seule présence d'une protéine quelconque n'assure pas nécessairement cette stabilité, car parmi les différentes fractions de protéines Harvard expérimentées, seule la fraction V, contenant 100 pour-cent d'albumine, est nettement active. On peut évidemment se demander comment il se fait que la solution de globuline Lilly est douée d'une certain activité. Remarquons tout d'abord que nous ignorons la composition de cette solution en ce qui concerne sa teneur en substances réductrices et autres stabilisateurs éventuellement présents. D'autre part, nous avons opéré, dans ce cas, sur une concentration de globuline voisine de celle de l'albumine plasmatique pour comparer l'activité de ces deux espèces de protéines. Cette concentration est, par contre, trop élevée lorsqu'on envisage la teneur globulinique totale du plasma normal ou ictérique. Ce-

pendant, nous n'excluons pas actuellement la possibilité d'une certaine activité anti-oxygène des globulines plasmatiques vis-à-vis de la bilirubine, mais nous estimons que la question demande de nouvelles recherches que nous n'avons pas encore réalisées faute de produits. Notons d'autre part, que l'action de l'albumine n'est pas uniquement de nature colloïdale. L'un de nous, a en effet montré précédemment que ni la gomme arabique, ni l'amidon, ni le glycogène ne sont anti-oxygènes vis-à-vis de la bilirubine, quoiqu'utilisés à concentration élevée.

Un deuxième fait qui résulte de nos expériences est le suivant: la propriété anti-oxygène du plasma alcalinisé n'est pas générale puisqu'elle ne s'exerce pas à l'égard d'autres substances facilement oxydables, tels certains polyphénols.

Si l'on compare maintenant la durée d'activité des solutions d'albumine Cutter, fraction V Harvard, albumines cristallisées Duke, sensiblement de même concentration en albumines, on voit que la difference est assez appréciable. Nous ignorons actuellement la signification de celle-ci.

Nous attirons d'autre part l'attention sur l'inactivité totale des acides aminés constituant la molécule albuminique, examinés isolément ou en mélange. Nous poursuivons nos recherches dans ce domaine.

CONCLUSIONS

(1) A la concentration albumino-plasmatique habituelle, l'albumine plasmatique est anti-oxygène à l'égard de la bilirubine en milieu alcalin.

(2) Cette action anti-oxygène n'est pas commune à toutes les protéines plasmatiques.

(3) Cette propriété de l'albumine est due à sa molécule envisagée comme telle.

(4) La propriété anti-oxygène du plasma alcalinisé est nulle vis-à-vis de certains polyphénols facilement oxydables, dans les mêmes conditions où elle se manifeste à l'égard de la bilirubine.

(5) Les expériences décrites dans ce travail sont en faveur de l'hypothèse suivant laquelle, dans le plasma, la liaison albumino-bilirubinique se ferait de telle façon que les fonctions carboxyles de la bilirubine seraient orientées vers la phase hydrique du milieu.

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ETHNOLOGY.—*Susquehannock Indian religion from an old document.*[1] C. A. WESLAGER, Archaeological Society of Delaware.

In 1943 a translation was made by Ira Oliver Nothstein of a graduation dissertation submitted June 14, 1731, to the faculty of Upsala University by Tobias Biorck, a Swedish student.[2] The dissertation was written in Latin according to the custom of the time. Apparently no importance was attached to it, inasmuch as it remained untranslated for more than 200 years. The student, as we know today, was the son of the Rev. Eric Biorck, a missionary sent to America in 1697 by Charles XI of Sweden. He served as minister of the Holy Trinity (Old Swedes) Church in Wilmington, Del., where his oldest son, Tobias, was born. When the minister and his family returned to Sweden in 1714, Tobias was then 11 or 12 years old. The dissertation which he later presented at Upsala described the planting of the Swedish Church in America and contained among other things a section devoted to native custom and religion. To the student of the American Indian these comments by a contemporary observer are worthy of careful review, especially since they relate to a tribe of Indians now considered extinct, the Susquehannock, alias the Minquas, an Iroquoian-speaking tribe that occupied the Susquehanna River region in Pennsylvania. It should be emphasized that of the few contemporary accounts relating to the Susquehannock nothing of their religion and little of their cultural pattern have been previously recorded.[3]

When the present writer undertook the preparation of a paper calling attention to that part of the translation dealing with the Susquehannock religion he found that a prior translation had been made by the late Walter Hullihen, president of the University of Delaware.[4] In comparing Hullihen's unedited and unpublished translation of the Indian section with that made by Nothstein, the writer was confronted with major differences in interpretation, and it became obvious that a third translation was needed to resolve the discrepancies. Miss Evelyn Holst Clift, a member of the faculty of the Department of Ancient Languages, University of Delaware, was consulted, and she subsequently made a third translation, carefuly comparing the differences in the two prior translations. It should be emphasized that she worked only with the Indian excerpts of the manuscript, disregarding the ecclesiastical portions relating to the Swedish Church. Miss Clift states that she finds that her translation more closely resembles Hullihen's, with some alterations, than it does Nothstein's. Her translation follows, with footnotes by the present writer:

Let us now come to the Indians, the ancient race of the American land, whom the Swedes call *Wildar*, unquestionably because they exist as wild men in the forests and deserted places. America is so crowded with them that it is believed that 300 separate peoples are found there using each a different tongue. They are said, however, to be growing less and less numerous

[1] Received June 18, 1946.

[2] *The planting of the Swedish Church in America*, by TOBIAS E. BIORCK, translated and edited by IRA OLIVER NOTHSTEIN, D.D., Augustana College, Rock Island, Ill., 1943.

[3] John Smith wrote the first detailed account of these Indians whom he called the "Sasquesahanocks," commenting on their large stature and warlike nature. He said: "They can make neere 600 able and mighty men, and are pallisadoed in their Townes, etc." *Travels and works of Captain John Smith*, edited by ARBER and BRADLEY, p. 54. Edinburgh, 1910.

A complete record of the historical references to the Susquehannock is given by H. FRANK ESHLEMAN, *Lancaster County, Pa. Indians*, Lancaster, Pa., 1908, and their geographical position is discussed by WILLIAM N. FENTON, "Problems Arising from the Historic Northeastern Position of the Iroquois," Smithsonian Misc. Coll. 100: 159–251.

Previous to 1763 the Susquehannock, also known as the Conestoga, are frequently mentioned in the *Colonial Records of the State of Pennsylvania*. These documents show that the Susquehannock had been defeated by the Five Nations Iroquois and their numbers greatly reduced as a result of warfare. In 1763 remnants of the tribe were exterminated by Scotch-Irish fanatics, the so-called Paxton Boys, near Harrisburg. For an account of this massacre see C. HALE SIPE, *Indian wars of Pennsylvania:* 463. Harrisburg, 1931.

[4] A typewritten copy of this translation is available at the Memorial Library, University of Delaware, Newark, Del.

and to be almost disappearing. Some of these are more powerful than others. We note now only the heathen *Minckusi* as being among the braver, around *Canistowa* and *Susquehana*.[5] They received the first Swedish settlers in America with such kindly feeling that, when other heathens wished to attack the Swedes with weapons, they came to their defense saying: "You must leave them in peace and quiet. But, if you wish to fight, you must fight with us." Hence, too, they called them *Hissimus*, that is, brothers (in their tongue).[6] Their territories are customarily described as to boundaries by rivers and certain hills. The king has a common name, *Sacheman*, meaning the same as "Dominus" (Lord). This "domination" in truth is especially noticeable in the handling of matters of greater importance, whether in connection with other heathens or with the Christians. In all other matters he is no more than equal of the rest. In very many particulars the customs and lives of these people are identical in type with the life of the Lapps. They are tall of stature and very erect.[7] Moreover, they are faithful, chaste, just, compassionate, not miserly, and happy in disposition. But in the treatment of captives they are rather severe.

As far as their religion goes, if it is to be called a religion, they recognize two Gods or spirits, which they call *Manetto's*. They say that the one is the ruler of celestial matters, the other of terrestrial. They perversely believe that the first, since he is good, need not be worshiped or feared, but that the second because he is evil is to be both feared and worshiped. Master A. Hesselius has portrayed the form of this (divinity) just about as it was cut on the door of a Swedish-American settler.[8] They indulge in various superstitions, taking an omen from various birds, snakes, and other animals which seem more fitting to them. As familiar spirits (genii) and household gods they have images of these objects of superstition, which they carry with them, ascribing to them their successes in hunting and every other fortunate event. It is even a custom at times for the images of these household gods to be inscribed and pricked on their arms and bones with a certain kind of thorn in such a way that they remain indelible; furthermore, it is customary for them to be cut into trees so that one can see from them what heathens are dwelling in this or that tract of land or have had their domiciles there before.

That after this life our heathens expect a

[5] Canistowa refers to Conestoga, a name used to refer to a creek and also Indian settlements on the creek. Biorck uses "Minckusi" to designate the Minquas or Susquehannock tribe. Lindeström uses the word "Minquesser" (see *Geographia Americae*, PETER LINDESTRÖM, translated by AMANDUS JOHNSON. Philadelphia, 1925). There is no doubt that Biorck has delimited his comments to the Minquas as the above text clearly reveals.

[6] Other contemporary documents confirm Biorck's statement that the Minquas and Swedes were on very friendly terms. Gov. Johns Rising wrote that the Minquas considered them as their "protectors." This relationship was a product of a deliberate attempt on the Swedes' part to cultivate friendship with the Minquas because of the great quantities of beaver pelts obtainable in the Minquas country. See AMANDUS JOHNSON, *The Swedish settlements on the Delaware*, vols. 1 and 2. Philadelphia, 1911.

[7] Note that John Smith also wrote that these Indians were tall.

[8] Andreas Hesselius, who succeeded the senior Biorck as minister as the church in Wilmington, left a journal to which Tobias Biorck refers in the above. The Journal was published in Swedish at Upsala, 1938, *Andreas Hesselii Anmarkningar Om Amerika*, by NILS JACOBSSON, but no English translation has yet been published. Under date of June 10, 1712, Hesselius entered the following in his Journal:

"Såg iag hoos en swensk Handelsman en figur, som Indianerna sielfwa hade målat sin Manettos skapnad, med then the fruchta och dyrcka: Liknelsen kommer närmast til ett warg-Hufwud, some grijnar och pustar uth eld och röök: Kroppen är en drakekropp, mycket tiock, men smalnar ut wid stiertten, ther några sällsamma kruus och characterer synas: Eljest hafwer Kroppen inga fötter eller wingar, untan allenast ett par uträckta armar och händer med kloor på fingren utspände til at grijpa något."

A free translation of the excerpt would be approximately as follows:

"I saw a figure which the Indians themselves had painted at a Swedish merchant's, the image of their Manetto, whom they fear and worship: the figure nearest resembles the head of a wolf, grinning grimly and emitting fire and smoke, the body is like the body of a dragon, very thick but tapering at the tail where some peculiar ornaments and characters are seen. There are no feet or wings attached to the body. Only a pair of arms stretched forth, the fingers of the hands were provided with claws and those extended as if they were about to take hold of something."

In his graduation dissertation Tobias Biorck included a sketch of the figure which he identifies as "*Manetto Indianorum.*" (See illustration, p. 33, of the Nothstein translation.) His sketch conforms closely with the above description. It should be noted that both Iroquois and Algonkian religious concepts included a "holder of the heavens" and an "earth bound twin brother," which are doubtless the basis for the above remarks relating to "good" and "bad" Manito.

more blessed one is indicated by the pipes, tobacco, and bottles made of animal skins, etc., which the others deposit in the mounds with the bodies. This they do in token of friendship, in order that, wheresoever the entrance to the better life befalls them at some time they may themselves enjoy the same furnishings. All days are held by them at one and the same value. No one is more sacred to them than another. In their sacrificial services, through which they believe the evil spirit is appeased so that nothing unfortunate may rush upon them, they behave in so many different ways that they would drive any sane person to stupefaction, even to amazement. These sacrifices, according to the matter in hand and the season of the year, are made with first-fruits of the harvest, of the hunt, of fishing, etc. The program and plan in accordance with which these (sacrifices) are instituted will be immediately apparent from the twofold example which is here appended.

The first sacrifice, after the successful hunt of a stag, is said to have been as follows: some people, a few, surrounded a hut which had been duly constructed and covered with bark and skins. Where the sacrificer had put tobacco on top of little stones which had been brought into the hut and heated with fire, another man, following him, poured water over them. Wherefore, because smoke thereupon rises on high, in like manner the sacrificer saying in a higher voice, repeated, *Kännäka, kännäka,* or sometimes hoo, hoo, turns his face toward the east. Moreover, when the sacrificer had become silent, the others, sitting near, made ridiculous sounding noises as they tried to imitate the uncouth sounds, some of the African cock [guinea-hen?] others of the squirrel, others of other animals. Amid this noise there were distributed to the guests two roasted stags, with bread made out of grain, ground *Majis* (which we usually call Turkish wheat) called by them *Kankis.*[9] Moreover, the sacrificer ate nothing meanwhile.[10]

The second example Master A. Hesselius saw with his own eyes. This sacrifice was made from the first-fruits of roots which are not very different from nuts and are dug up by the heathens in the swamps; they are there [i.e., among the heathens] called *Tachis,* in English hopnuts. These, first dried by the heat of the sun, they cook beneath the open sky in a jar or a bronze kettle placed on the fire. While this culinary operation is being conducted and while the others are leaping around in a circle, an Indian woman finally comes forth, with her hair loosened over her shoulders, and with a spoon stirs the food again and throws a part of the same food into the fire, an action which those dancing around approve by the shout which they utter. Afterwards they consume the food as if it were food prepared on this occasion for themselves. These and other sacrifices of the Americans are usually called, in their native language, *Kinticka,* that is a rather well-known [or rather crowded] gathering or wedding.[11]

[9] This obviously refers to corn.

[10] Some similarities between this ceremony and a sacrificial feast recorded by Zeisberger among the Delawares may be distinguished. See DAVID ZEISBERGER, *History of the North American Indians,* ed. by HULBERT and SCHWARZE: p. 137. FRANK G. SPECK, *Oklahoma Delaware ceremonies, feasts and dances,* p. 59, 1937, also discusses sacrifice feasts among the Delawares wherein family groups often celebrate the first taking of produce of the chase. Dr. William N. Fenton, of the Bureau of American Ethnology, in a personal letter dated August 10, 1945, has kindly given me the following information relative to a Five Nations rite, which bears some similarities to Biorck's account:

"In September, about the time of the first deer hunt, the Little Water Medicine Society meets to renew the strength of the Medicine. At this session four groups of songs are sung of which the third, sung only at this meeting, is to renew the fur on the animals who then don winter coats. Certain aspects of the ceremony suggest that the original meetings were held in a sweat lodge. A basket of tobacco is set out for the members to contribute a share. Some of this is used to invoke the spirit members, the animal tutelaries, and the rest is smoked. At Tonawanda pinches of tobacco are set out for each group of songs—eight in all—four pinches and two pinches per group for the male and female songs. Between songs when the fire is down, they raise up the light—kindle the fire and pass berry water. At the end is a terminal feast. The conductor passes a hog head, anciently a bear or deer head, and all the members Kah Kah! like crows or buzzards picking at a dead carcass. There is also cornbread, I think. . . . I do not recognize [the meaning of] Kännäka."

[11] As in the first ceremony described, there are elements in the second suggestive of both Algonkian and Iroquoian rites. The use of fire is reminiscent of the fire symbolism among the Delawares described by FRANK G. SPECK, *Delaware Indian Big House Ceremony:* 47. Harrisburg, 1931. The Delawares were not pyrolatrists, but fire, as a spirit force, subordinate to the Great Spirit, was considered an agency of purification and invigoration. Similarly, the sacrifice of the first fruit also harks back to Delaware religious beliefs. SPECK, *ibid,* p. 12, discusses and analyzes

CONCLUSIONS

The description written by Tobias Biorck purports to be an account of certain customs and religious practices of the Minquas or Susquehannock Indians. His information was based on boyhood observation in America and information received from Andreas Hesselius and doubtless from his father Erick Biorck. While his remarks are inconclusive, nevertheless they represent the only contemporary account of Susquehannock ceremonial rites and as such warrant consideration. It would be extremely hazardous to draw conclusions from the comments of a European who was unschooled in ethnological techniques and who entertained religious prejudices; nevertheless, in the absence of other data, the account must be accepted at face value. According to details given by Biorck, the Susquehannock, although an Iroquoian-speaking people seem to have practiced ceremonial rites akin to the Delaware, an Algonkian people. Since the latter are believed to have been the older occupants of the region, one may be justified in inferring that the Susquehannock ceremonial pattern had undergone change due to Algonkian influence.

the term "kinticka" or "ka'ntika," meaning "he is dancing."

In addition, the ceremony described could well resemble an earlier Iroquois ceremony of the pattern described by William N. Fenton, *Tonawanda Longhouse Ceremonies: Ninety Years After Lewis Henry Morgan*, Bur. Amer. Ethnol. Anthrop. Papers, No. 15. Smithsonian Institution, 1940."

ENTOMOLOGY.—*Descriptions of three new species of mosquitoes of the genus* Aedes, *subgenus* Finlaya, *from New Guinea.*[1] WILLARD V. KING, Colonel, and HARRY HOOGSTRAAL, Captain, Sn.C., A.U.S. (Commnicated by ALAN STONE.)

Aedes (Finlaya) tsiliensis, n. sp.

This is a distinctive species, characterized by a large white scutal patch, white markings on the femora and tibiae, and apical as well as basal white rings on the first segment of the mid and hind tarsi.

Male.—Head: Proboscis dark-scaled, slightly longer than fore femur. Palpus about as long as proboscis; long segment with a white ring in the middle, apical segment completely white, sub-apical segment all dark; long slender bristles ventrolaterally from last two segments and apex of long segment. Antenna almost as long as proboscis, densely plumose, the long hairs directed mostly in two planes. Clypeus black, nude. Scales of vertex narrow curved, a median area silvery white, bordered on each side by an area of dark and scattered white scales, a patch of broad white scales laterally extending forward as a narrow line along eye margin; numerous upright forked scales on vertex, palest in median area. *Thorax:* Scutum covered across front half with coarse, lanceolate, silvery-white scales, continued over upper half of posterior pronotum. (Central part of disk of holotype and paratypes rubbed, with a few remaining fine white scales posteriorly. The original notes on this species read: "Mesonotum with a striking patch of linear white scales across front half and upper part of *ppn* and a broad line around antescutellar space.") Scutellum with narrow and lanceolate silvery-white scales on each lobe (partly rubbed). Postnotum black, nude. Anterior pronotal lobe largely covered by broad silvery-white scales and long black bristles. Posterior pronotum covered on upper half with narrow silvery-white scales, smaller than those on scutum. Postspiracular area black with about six bristles. Patches of broad silvery-white scales on upper and lower posterior sternopleuron, on paratergite, in front of prealar bristles, and a wide patch on mesepimeron curving from upper posterior to middle anterior borders; no lower mesipmeral bristle. Propleuron with broad silvery-white scales and about six bristles. Wing length 3 mm; scales dark except for a short line of white scales at base of costa and vein 1; lateral scales of veins 2 to 4 elongate, those on the tips

[1] From the 19th Medical General Laboratory, U. S. Army. Contribution No. 11 from the Entomology-Mammalogy Department. Received July 2, 1946.

slightly shorter and broader; anterior fork cell about one and a half times as long as its stem arising slightly closer to base of wing than posterior cell; posterior cross vein closer to base of wing than mid by more than its own length. Haltere stem yellowish, knob dark. Coxae with patches of silvery-white scales. Fore femur dark, with a narrow basal white ring and a large white spot midway of posterior surface; mid femur similar but in addition with a conspicuous apical white spot; hind femur completely white on basal half, the apical half dark except for an apical white ring, lengthened below. Fore tibia with an anterior apical white spot about one-fifth its length, the posterior surface entirely dingy white; mid tibia with a narrow subapical white ring extending basad as a line to middle on dorsal surface; hind tibia with a small dorsal apical white spot only. Fore tarsus all dark; mid tarsal segment 1 with a white ring on basal and apical thirds, segment 2 white on basal third; hind tarsus with a basal white spot and a narrow apical ring on segment 1, and a narrow basal ring on segment 2; other segments all dark; fore and mid tarsal claws subequal, the larger claw toothed. *Abdomen:* Tergites IV to VI with dorsal basal median white spots about half length of segment, narrowly separated from lateral spots; tergites II, III, and VII with median spots much smaller; large basal lateral silvery spots on tergites II to VII, those on anterior segments about half length of segment, on posterior segments almost full length; tergite VIII almost entirely silvery-scaled; sternites silvery basally, black apically, without erect scale tufts; coxites silvery-scaled on outer surfaces. *Hypopygium* (Fig. 1, from a paratype): Coxite four times as long as mid width, strongly compressed laterally, the outer surfaces densely clothed with scales and bristles; subbasal lobe in the form of an elongate ridge covered with long bristles; apical half of coxite with a dense patch of long, striated, pointed scales along the inner margin of the lower fold and fine bristles from the upper fold. Style two-fifths as long as coxite, slender, curved, finely pilose basally and along inner side, with a short, subapical hair; terminal appendage nearly one-fourth length of style. Paraprocts strongly curved and heavily sclerotized apically, each ending in two or three large and two or three small teeth. Phallosome bullet-shaped. Stem of harpago slender, curved, pilose basally, with one long and one shorter subapical bristle; blade not quite as long as stem, arising slightly subapically, greatly widened basally and tapered to a blunt tip. Ninth tergite with well separated lobes, each bearing four stout bristles.

Female and larva.—Unknown.

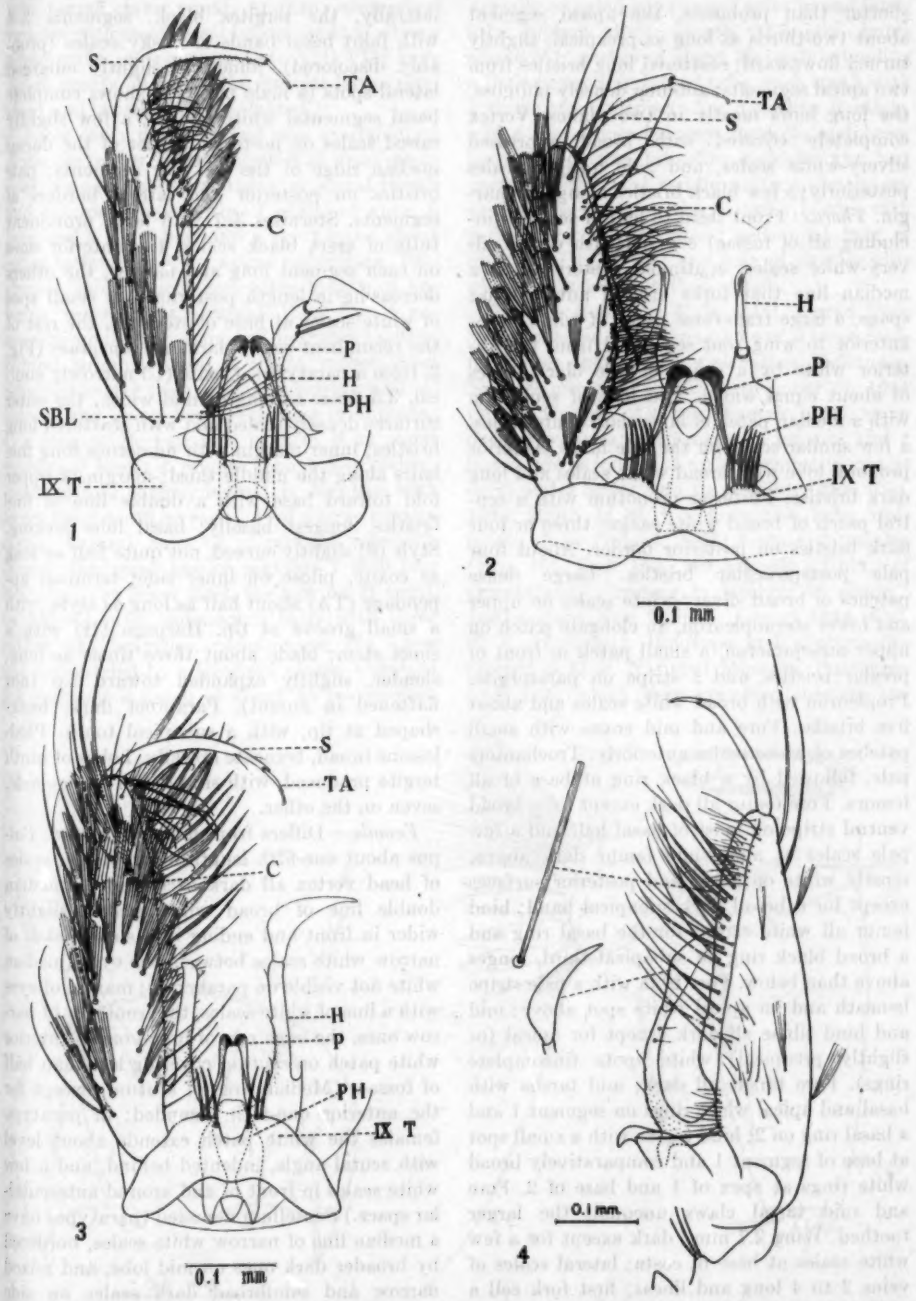
Types.—Holotype: Male (K107) reared from larva collected in a tree hole at Tsili Tsili on the Watut River (a branch of the Markham River) in the former mandated territory of eastern New Guinea, September 1943 (W. V. King collector). *Paratypes:* 2 males (one in very poor condition) same data as above. The holotype and one paratype are deposited in the United States National Museum.

Remarks.—This species is very distinct from any other Australasian *Finlaya* but appears to be related to several Oriental species described as having a white patch on the scutum, apical and basal banding on some of the tarsal segments, and nontufted scaling of the abdominal sternites. *A.* (*F.*) *gubernatorius* (Giles) of India, the closest of these, differs in having the scales on vertex and posterior pronotum all broad, tarsal markings more extensive, male palpi all dark, coxite without modified pointed scales, etc. Other Indian species of this group (*A. assamensis* (Theobald), *A. cogilli* Edwards, etc.) have, in addition, flat scales on the scutellum. *A.* (*F.*) *seoulensis* Yamada of Korea (also known from Peiping, China) has narrow scales on the posterior pronotum and scutellum, as in *tsiliensis*, but differs (according to available description) in having broad scales on most of the head vertex, and apical and basal banding on the second as well as the first segment of the hind tarsi and the first segment of the fore tarsi. In the male the blade of the harpago is slender for entire length and the coxite lacks the patch of pointed scales.

Aedes (Finlaya) plumiferus, n. sp.

This species (Fig. 6) is immediately recognizable in the known Australasian fauna by the large tufts of scales on the abdominal sternites. The scutum has a large anterior patch of silvery-white scales, and the first segment of the mid and hind tarsi have apical as well as basal white rings.

Male.—Head: Proboscis about equal to fore femur, black; palpus all black, slightly



FIGS. 1–4.—Male genitalia: 1, *Aedes tsiliensis;* 2, *A. plumiferus;* 3, *A. quasirubrithorax;* 4. *A. keefei.*

shorter than proboscis, the apical segment about two-thirds as long as preapical, slightly turned downward; scattered long bristles from two apical segments; antenna densely plumose, the long hairs mostly in two planes. Vertex completely covered with broad appressed silvery-white scales, and pale upright scales posteriorly; a few black bristles along eye margin. *Thorax:* Front third to half of scutum (including all of fossae) covered with coarse silvery-white scales, continued posteriorly as a median line that forks around antescutellar space; a large transverse patch of white scales anterior to wing root separated from the anterior white by a stripe of fine black scales of about equal width. Mid lobe of scutellum with a median patch of lanceolate white scales, a few similar scales on the side lobes. Anterior pronotal lobe with broad white scales and long dark bristles. Posterior pronotum with a central patch of broad white scales; three or four dark bristles on posterior border. About four pale postspiracular bristles. Large dense patches of broad silvery-white scales on upper and lower sternopleuron, an elongate patch on upper mesepimeron, a small patch in front of prealar bristles, and a stripe on paratergite. Propleuron with broad white scales and about five bristles. Fore and mid coxae with small patches of white scales anteriorly. Trochanters pale, followed by a black ring at base of all femora. Fore femur all dark except for a broad ventral stripe on most of basal half and a few pale scales at apex; mid femur dark above, mostly white on lower and posterior surfaces except for a broad dark subapical band; hind femur all white except for the basal ring and a broad black ring on subapical third, longer above than below. Fore tibia with a pale stripe beneath and an apical white spot above; mid and hind tibiae all dark except for apical (or slightly preapical) white spots (incomplete rings). Fore tarsus all dark; mid tarsus with basal and apical white rings on segment 1 and a basal ring on 2; hind tarsus with a small spot at base of segment 1 and comparatively broad white rings at apex of 1 and base of 2. Fore and mid tarsal claws unequal, the larger toothed. Wing 2.7 mm., dark except for a few white scales at base of costa; lateral scales of veins 2 to 4 long and linear; first fork cell a little longer than its stem; cross veins well separated. *Abdomen:* Strongly compressed laterally, the tergites black, segments 3–6 with faint basal bands of dusky scales (probably discolored), joined to slightly enlarged lateral spots (a male paratype shows complete basal segmental white bands); a few slightly raised scales on posterior border of the dorsal median ridge of the last few segments; pale bristles on posterior and lateral borders of segments. Sternites 3–7 with large prominent tufts of erect black scales, the anterior ones on each segment long and narrow, the others decreasing in length posteriorly; a small spot of white scales at base of sternites, the rest of the recumbent scales dark. *Hypopygium* (Fig. 2, from a paratype): Coxite (C) narrowly conical, 3.5 times as long as mid width, the outer surfaces densely scaled and with scattered long bristles; inner margin with numerous long fine hairs along the middle third; margin of upper fold toward base with a double line of fine bristles, longest basally; basal lobe lacking. Style (S) slightly curved, not quite half as long as coxite, pilose on inner side; terminal appendage (TA) about half as long as style, with a small groove at tip. Harpago (H) with a short stem; blade about three times as long, slender, slightly expanded toward tip (not flattened in mount). Paraproct dark, beak-shaped at tip, with a subapical tooth. Phallosome broad, truncate apically. Lobes of ninth tergite produced, with six bristles on one side, seven on the other.

Female.—Differs from male as follows: Palpus about one-fifth length of proboscis; scales of head vertex all dark except for a median double line of broad white scales, slightly wider in front and ending in a small patch of narrow white scales between the eyes (median white not visible on paratypes); margin of eyes with a line of white scales, the front row of narrow ones, the back row of broad ones. Anterior white patch on scutum covering less than half of fossae. (Median area of scutum, except for the anterior one-fifth, denuded; in paratype females the white patch extends about level with scutal angle, indented behind, and a few white scales in front of and around antescutellar space.) Scutellum denuded (paratypes have a median line of narrow white scales, bordered by broader dark ones on mid lobe, and mixed narrow and semibroad dark scales on side lobes); wing length 3.4 mm; first fork cell about half again longer than its stem; fore and

mid tarsal claws equal, toothed; abdominal tergites with small basal lateral spots of silvery white scales on segments II to VII; VIII very small, nearly all white, the sternite large; cerci short and broad, partly retracted.

Larva (only one damaged skin available).—Antenna rather short (length 0.25 mm), glabrous, a single fine hair arising at apical fourth and reaching beyond tip of shaft; at apex, a long and a short hair and a short spine about equal in length to the apical appendage. Preclypeal spines about two-fifths length of antenna, rather stout, straight. Head hair A unusually small with four fine branches, arising behind antennal base; B single, rather short (slightly longer than antenna), arising well inside of and about level with base of antenna; C a long single hair well back of B at about middle of head; *d* minute, about 5-branched, inside of and slightly behind B. Mentum with seven stout teeth on each side of a large median tooth. Lateral hairs of abdominal segments strong, the upper one on segment I with four branches, the lower bifid, the hair on II trifid, on III–VI bifid; submedian hairs with three rather fine branches, nonplumose, the bases not surrounded by sclerotized plates. Comb of 8th segment a patch of about 35 scales, each apically rounded and fringed apically and laterally. Siphon stout, length 0.65 mm, index about 2:1; pecten of about 20 teeth extending a little beyond middle of tube, each tooth with a single stout median or sub-median denticle, and a fine fringe between denticle and base; hair tuft of five branches opposite the last pecten tooth. Anal saddle not completely encircling the segment, the posterior border with rather long spines; dorsal subcaudal hair of four equal branches; one pair of slender gills visible, a little longer than saddle.

Types.—Holotype: Male (344), reared from larva collected in buttress hole of a large rainforest tree about 250 feet elevation, Hollandia, Netherlands New Guinea, November 21, 1944 (W. T. Nailon). *Allotype:* Female (344), same data. *Paratypes:* Two males, 3 females and 1 larval skin as follows: 1 male (terminalia mount only) and 1 larval skin in poor condition (No. 1985, 220th M. S. U.), from tree hole, Hollandia, New Guinea, 1945; 1 male, 3 females (No. 166 and 165, respectively, Univ. of Queensland), "resting in treehole in shade," Lae, eastern New Guinea, August 1944 (Cpl. F. J. Armbrust). Holotype and allotype deposited in U. S. National Museum. Paratypes from Lae (which were examined through the

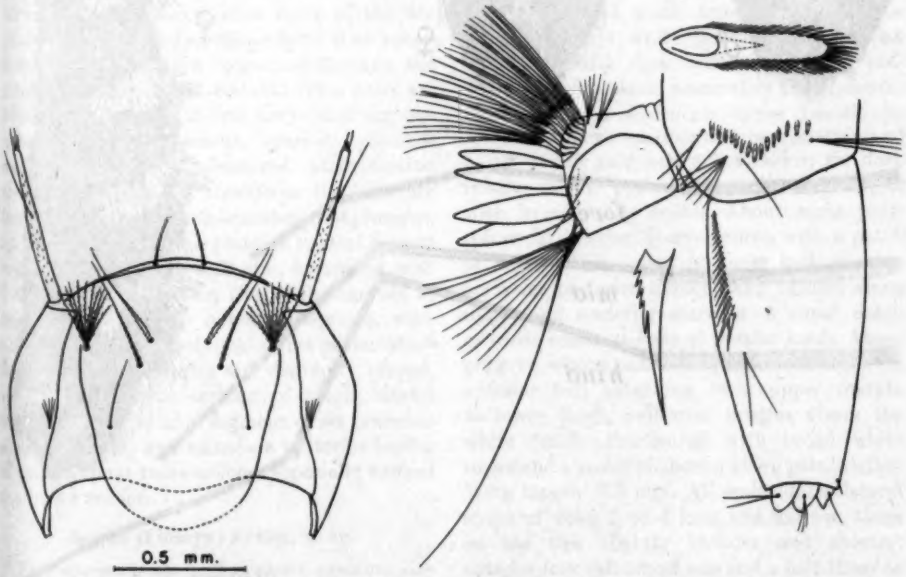


FIG. 5.—Head and terminal appendages of larva of *Aedes keefei*.

kindness of Miss E. L. Marks) are to be returned to the University of Queensland. Two additional females (Lot 226) are at hand but their markings are badly discolored from wetting with the mounting medium. These were reared from larvae from a tree hole near lot 344 October 27, 1944 (H. Hoogstraal and J. Toffaleti).

Remarks.—The larvae in Lots 226 and 344 were associated with those of *Aedes* (*Finlaya*) *notoscriptus* (Skuse), *A.* (*Stegomyia*) *albolineatus* (Theobald), and *Megarhinus splendens* (Wiedemann).

A. plumiferus belongs to a small sub-group of Oriental species having tufts of long scales on the abdominal sternites, both apical and

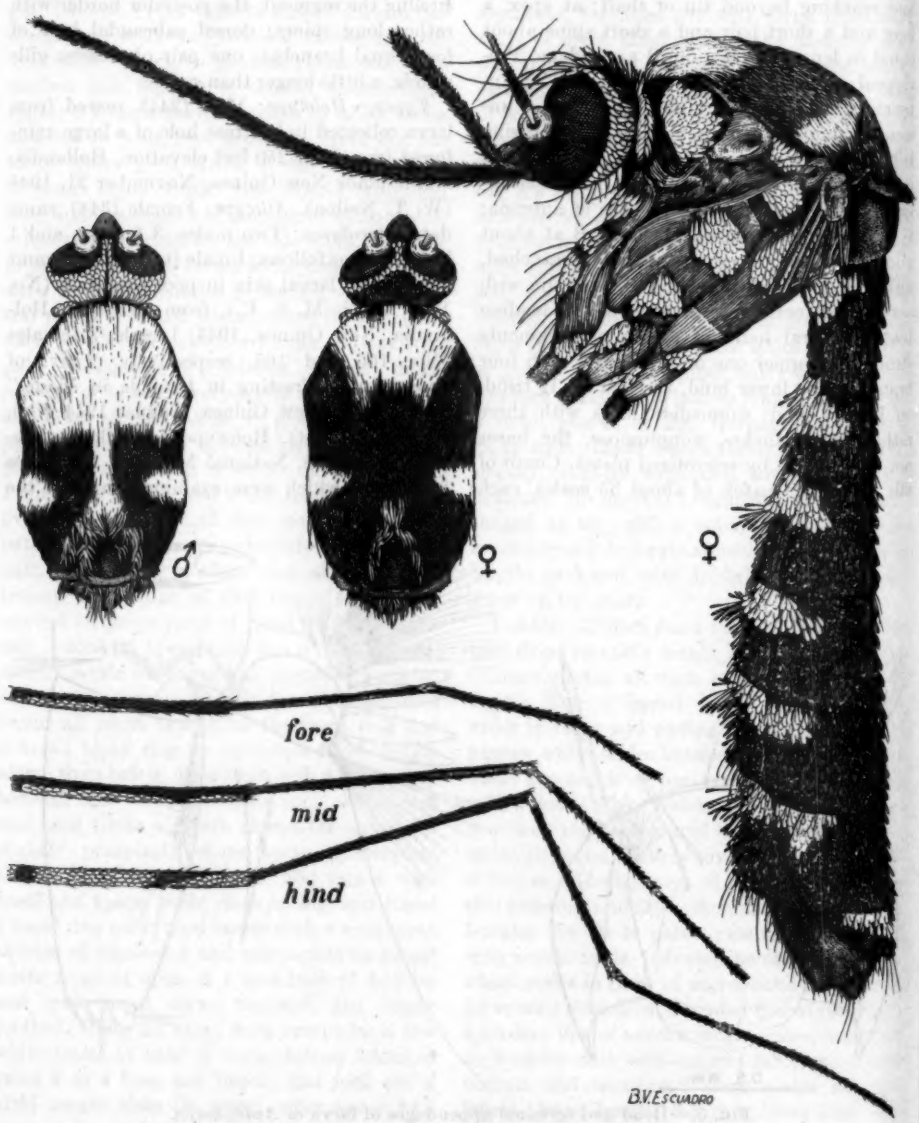


FIG. 6.—Ornamentation of adults of *Aedes plumiferus*.

basal white rings on the first tarsal segment of the mid and hind legs and a large patch of white on the scutum. These species include *A. prominens* (Barraud) and *A. khazani* Edwards of India, *A. melanopterus* Giles of the Philippines, and *A. watasei* Yamada of Japan. It differs from the first two in having narrow scales on the scutellum, only white scales on the head in the male and a median white strip on the head in the female. The posterior pronotum is also bare of scales in *prominens*. *A. watasei* (of which only the female has been described) differs in having tufts of long scales on tergites 5–7 similar to those on the sternites, broad basal segmented white bands on the venter and flat scales on the scutellum. From a comparison with specimens of *A. melanopterus* recently obtained in the Philippines, *plumiferus* is found to be very similar, although the larva is distinct. In the male of *melanopterus* the palpi seem to be somewhat shorter, failing to reach the base of the labella, the blade of the harpago is more distinctly widened at the apical third, the lobes of the ninth tergite have four bristles each instead of six or seven, the base of the style is swollen and the bristles near the base of the coxite form more of a patch. The principal difference between the larvae is in the submedian hairs of the abdominal segments. In *melanopterus* (two specimens of which were examined through the kindness of Dr. K. L. Knight) these hairs are branched from two to six times and are unusually long and stout, sparsely plumose and have a small sclerotized plate around the basal papilla. In *plumiferus* the hairs are less than half as long, 3-branched, nonplumose, and not arising from a plate. A typical hair on segment 5 measured 0.22 mm, compared with 0.48 mm for a hair on the same segment of *melanopterus*. Other minor differences were noted as follows: preclypeal spines in *melanopterus* somewhat stouter and distinctly curved, saddle hair double instead of single, dorsal subcaudal hair of anal segment of six branches instead of four, and spines on posterior border of saddle about twice as long, especially toward the lower corner.

Aedes (Finlaya) keefei, n. sp.

This species is somewhat above medium size and has an ornamented scutum consisting of faint median and submedian golden lines and wider lateral curved lines. The hind tarsal segments have broad basal bands and segment 5 is entirely white. It is closely related to the Australian species *A.* (*F.*) *quasirubrithorax* (Theobald).

Female.—Head: Proboscis dark-scaled, about equal in length to fore femur. Palpus dark-scaled, one-sixth as long as proboscis. Torus tan. Clypeus black, nude. Vertex with scattered lanceolate silvery scales, a denser border along eyes, and numerous dark upright forked scales; lateral surface with broad silvery-white scales. *Thorax:* Scutum and pleura with yellowish-brown integument; scutum covered with fine dark-brown scales, three small patches of white scales with yellowish tinge on anterior border; faint median and submedian lines each represented by a single broken line of silvery scales reaching the middle of scutum; laterally with a narrow line of white scales extending from the anterior margin to the scutal angle, there broadening around the posterior border of the fossa and then continuing as a narrow line nearly to the scutellum; a few narrow pale scales over the wing bases. Scutellum densely clothed with silvery white scales, broad appressed ones on mid lobe, long lanceolate ones on side lobes, narrowest at outer side. Postnotum yellowish, nude. Anterior pronotal lobe with lanceolate white scales with yellowish tinge, and with dark bristles. Posterior pronotal lobe with black, moderately broad, spatulate, appressed scales on upper two-thirds, somewhat narrower ones on upper margin and a few broad pale scales low down; six dark bristles along posterior margin. Paratergite with broad white scales. About eight postspiracular bristles. Sternopleuron with a patch of broad white scales on upper half, another on lower posterior border; long bristles along upper and posterior margins. A small patch of white scales at base of prealar knob. Mesepimeron with a patch of broad white scales on anterior half extending from upper margin to lower third; yellowish bristles above the white patch. Propleuron with broad white scales and a group of about 14 long pale bristles. Wing length: 3.8 mm. All scales dark; lateral scales of veins 2 to 4 long and narrow, those on the tips slightly broader and shorter; anterior fork cell amost one and a half times as long as its base, arising about level with posterior fork cell; posterior cross vein more basal

than mid by at least twice its own length. Haltere entirely yellow. Coxae with pale scales, a patch of dark ones on anterior surface of fore coxa. Fore and mid femora each with a broad line of pale yellowish scales on inner surface for about half its length; basal two thirds of both inner and outer surface of hind leg pale yellow; knee spots silvery white on all legs. Tibiae completely dark. Fore and mid tarsi with distinct white basal rings on segments 1 and 2, and a small spot on 3; hind tarsus with broad white rings on segments 1–4, that on 4 about two-fifths length of segment, segment 5 entirely white; fore and mid tarsal claws about equal and toothed. Tergites dark-scaled with metallic reflection, narrow median basal pale spots on III to VI almost connected with lateral spots; large silvery white basal lateral spots on II to VII, becoming gradually larger on the apical segments, extending full length of segment and onto dorsum; sternites broadly pale-scaled basally, with narrow posterior dark bands; eighth sternite compressed laterally, small, scaleless; cerci broad, partly retractly.

Male.—Differs from female as follows: Palpus about equal in length to proboscis, the two apical segments turned downward; a ventrally directed row of long bristles from tip of long segment and basal portion of subapical segment, sparse short bristles on remainder of the two apical segments; white basal spots on the two apical segments, about one-third their length, and a white ring in the middle of long segment; antenna densely plumose, the long hairs arranged mostly in two planes; first fork cell about a third longer than its petiole; abdominal tergites III-V with complete, rather wide, white basal bands, a narrow one on VI. *Hypopygium* (Fig. 4): Coxite long (0.45 mm) and slender, nearly four times as long as mid width, heavily scaled on outer surfaces, inner fold extending to tip; basal lobe lacking, represented by a small patch of bristles, the basal one of which is much longer than the others; apical half of the margin of lower fold with a dense line of long bristles, slightly modified, their stems showing one or two striations; above these on both the upper and lower folds, several rows of long very fine hairs. Style very slender, slightly more than a third as long as coxite; terminal appendage about one-fourth as long as style. Harpago with a long slender stem (reaching about to middle of coxite), its basal half sparsely pilose; blade slightly shorter than stem, much widened near base, curved and tapered to a slender tip. Paraproct with a black, beak-like tip and a small subapical tooth. Phallosome broad, simple. Lobes of ninth tergite produced, each with three bristles.

Larva (Fig. 5).—Head about 0.8 mm long, half again as wide; antenna long and slender, about two-thirds as long as head, spiculate, a single hair from middle of shaft, reaching beyond tip of shaft; two long and two short apical bristles and a finger-like appendage. Preclypeal spines long and slender. Head hair A a large tuft of about 10 branches, B and C long and single, B about level with base of antenna, C slightly ahead and inside of B, *d* a multiple tuft of rather long hairs between the bases of B; *e* single or forked at middle, *f* with about 7 branches. Anterior submedian prothoracic hairs 1 to 3 set on a plate, No. 1 a short tuft of about six branches, 2 long, single, 3 long, bifid. Upper lateral hair of abdominal segment I with five or six branches, the lower with four; lateral hair on II 3-branched, on III to V double; submedian hairs long, double. Comb of eighth segment a long, even, curved row of about 18 teeth, each rounded and evenly fringed. Air tube short and stout, index about 2:1 (length 1.2 mm); acus present; pecten of about 20 closely set teeth on basal half of tube, the individual tooth long, sharp, with 5-7 denticles on one side of the widened basal half, the teeth progressively longer toward tip of pecten; tuft of two or three branches beyond pecten. Anal saddle covering a little more than half of segment, spiculate on posterior border; lateral hair single; one or two small tufts in front of ventral grid; dorsal subcaudal tuft with about ten branches, the ventral subcaudal hair single as usual. Anal gills small, slightly longer than the saddle.

Types.—Holotype: Female (K 128B-3) reared from larva collected in a stump hole near K. B. Mission, Milne Bay, Papua, New Guinea, October 1943 (Chaplain A. M. Keefe collector). *Allotype:* Male from same lot. *Paratypes:* 1 male, 8 females (with several larvae and pupal skins and whole larvae) as follows: 2 females (K 128B-3), same data as holotype; 1 male (H-1-1) seven females (H-313-1, H-1-5, H-1-2, H-1-10, H-1-7), "Hilimoi, Milne Bay, Papua, N. G. Penn & Bick" (probably late 1943); 1 female (46 B) "Sariba Is. N. G. 1-10-44. T. K.

Ruebush" (probably in Milne Bay area). Holotype and allotype deposited in U. S. National Museum. The paratypes from Hilimoi and Sariba Islands were examined in the collection of this museum. One paratype from lot K 128B-3 to be deposited in the museum of the Division of Economic Entomology, Council for Scientific and Industrial Research, Canberra, A. C. T., Australia.

Remarks.—This species is very similar in general appearance to *A.* (*F.*) *quasirubrithorax* (Theobald) but differs distinctly in having broad (instead of narrow) scales on the mid lobe of the scutellum, and small, flat, black scales (instead of narrow yellowish ones) on the upper half of the posterior pronotum. The scutal pattern is also less distinct. In this respect most of the New Guinea specimens of *quasirubithorax* that have been examined have a less distinct pattern than specimens from Australia but seem otherwise to be very similar. In the male genitalia of *quasirubrithorax* (Fig. 3, from a Hollandia, New Guinea specimen) most of the modified scales on the inner margin of the lower fold of the coxite are distinctly broader than those in *keefei* and the wider ones show three or four striations.

From the original collection at Milne Bay (K 128B-3), seven adults were reared by the senior author from larvae that were thought to represent a single species. The adults were found to consist of one male, three females of a new species, and two males, one female of *quasirubrithorax*. The larvae had not been individually isolated but all the skins were saved. A tentative association of the larvae of the two species was made on the basis of the number of each (four of one and three of the other). This association was later confirmed by larvae in the U. S. National Museum associated with a collection of adults of the new species from Hilimoi, Milne Bay. The larval material consisted of several whole larvae and three larval skins, at least two of which appeared to be associated by subnumbers ("1:7" and "1:10") with individual adults. In the Museum collection there was found also a series of adults and larvae of *quasirubrithorax* bearing Roberts lot numbers and likewise collected in the Milne Bay area. While the larvae of the two species are very similar, two slight differences in hair branching, which appeared to be constant, were noted. In *quasirubrithorax* head hair B was double or sometimes triple on each of fourteen larvae examined (including those in lot K 128B), and hair 3 of the submedian prothoracic group was single on each; in *keefei* head hair B was single on at least one side, usually on both sides, on nine specimens, while prothoracic hair 3 was usually double. In specimens of both species the airtube is distinctly shorter in comparison to the diameter (index about 2:1) than that shown for Australian *quasirubrithorax* by Lee (*Atlas of mosquito larvae of the Australasian Region*, 1944, p. 62), in which the index is 3:1 or more. The comb scales are also apically fringed instead of bare as illustrated by this author.

A. quasirubrithorax has not previously been reported from New Guinea. In addition to the Milne Bay records, we have three females and a male (lots 811 and 848) reared from larvae collected in tree holes in March 1945 by members of the 19th Medical General Laboratory in the Hollandia area of northern Netherlands New Guinea, and one female from the island of Kiriwina (east of New Guinea) collected in August 1943 by the 5th Malaria Survey Unit.

We have also a female (Lot 796) collected while biting on Mount Defonsero in the Cyclops Range, Hollandia area, in March 1945 (W. R. Fullem and H. Cook collectors), which differs from both the previously mentioned species in having broad white scales on all lobes of the scutellum. The specimen is so badly denuded and broken, however, that its relationship can not be determined.

ENTOMOLOGY.—*Notes on some Ashmeadian genotypes in the hymenopterous superfamily Chalcidoidea.*[1] A. B. GAHAN, U. S. Bureau of Entomology and Plant Quarantine, and O. PECK, Division of Entomology, Department of Agriculture of Canada. (Communicated by C. F. W. MUESEBECK.)

In Ashmead's monograph of the Chalcidoidea (Mem. Carnegie Mus. 1: 225–551. 1904) a number of new genera are proposed with the designation of a genotype for each. Many of these genotypes were manuscript species for which the only characterizations given in the work were the descriptions in the generic keys. Type localities were indicated for none of those species. In a few instances a species was cited as the genotype of a particular genus on one page and a different genotype listed for the same genus on another page. In one instance a typographical error resulted in a name entirely different from that which the author obviously intended. Several of these Ashmead genera and species have been redescribed by Girault as new under the same or different generic and specific names. A few have been treated by other authors. These subsequent references are scattered and not always easily traced.

The object of this paper is to list these genotypes together with their type localities and pertinent citations to subsequent literature and to clear up, so far as possible, the confusion regarding some of the species involved. Fortunately we have been able to consult not only the types in the United States National Museum but also those from the Carnegie Museum in Pittsburgh, the two collections comprising practically all the material that formed the basis of Ashmead's monumental work.

In the second part of the monograph (pp. 394–551) a number of the new genera and their genotypes are more fully described. These species have not been included in the following list unless supplemental data of interest needed to be added. Likewise excluded from the list are those genotypes of which descriptions had been published prior to publication of the monograph.

[1] Received July 3, 1946.

Alloderma maculipennis Ashmead: 273, 365.[2] Type in U. S. National Museum, from Sydney, New South Wales, Australia. Ashmead's type redescribed as *Coelocybelloides bioculatus* Girault (Mem. Queensland Mus. 5: 224. 1916).

Alophus flavus Ashmead: 353, 365, 520. Type in collection of Carnegie Museum, from Chapada, Brazil. On pages 353 and 365 Ashmead cites *A. flavus* as type of the genus, but on page 520, following the description of the genus, he includes only one species, viz., "*Alophus brasiliensis* sp. n." There are no specimens in the U. S. National Museum collection and none in the Carnegie Museum collection labeled *A. flavus* Ashmead, and apparently there is no description of an *A. flavus* in the literature other than that in the generic key on page 353 cited above. It seems apparent that the specific names *flavus* and *brasiliensis* both refer to specimens in the Carnegie Museum collection labeled *Alophus brasiliensis*. Since *flavus* has page precedence, and since that name has been cited as the genotype by Ashmead, and later by Gahan and Fagan in their genotype catalog of chalcidoid genera (U. S. Nat. Mus. Bull. 124: 10. 1923), we shall retain the name *flavus* for the species and consider *brasiliensis* a synonym. *Alophus* preoccupied, replaced by *Alophomyia* Ashmead (Proc. Ent. Soc. Washington 6: 126. 1904).

Aphobetoideus comperei Ashmead: 328, 366. Type in U. S. National Museum, from Swan River, New South Wales, Australia. Species redescribed by Smith and Compere (Univ. California Publ. Ent. 4: 312. 1928).

Aximogastra bahiae Ashmead: 261, 367, 463. Type in U. S. National Museum, from Bahía, Brazil.

Aximopsis morio Ashmead: 259, 460; pl. 22, fig. 6. Type in collection of Carnegie Museum,

[2] The numbers cited following the specific names refer to pages in the Mem. Carnegie Mus. 1, 1904.

from Santarém, Brazil. On page 367 Ashmead indicates *A. bahiae* Ashmead as the genotype, but this is evidently a confusion with *Azimogastra* Ashmead, of which *A. bahiae* is the type.

Blatticida pulchra Ashmead: 305, 368. Type in U. S. National Museum, from Mulgoa, New South Wales, Australia. Reared in December 1891 from roach eggs on orange leaves by A. Koebele.

Brachycaudonia californica Ashmead: 283, 368. Type in U. S. National Museum, from Los Angeles County, Calif.

Bruchobius laticeps Ashmead: xi, 314. Type in U. S. National Museum, from Washington, D. C. Species redescribed by Crawford (Proc. U. S. Nat. Mus. **45**: 250. 1913).

Cecidoxenus nigrocyaneus Ashmead: 274, 369. Type in U. S. National Museum, from Flemington, New South Wales, Australia. Ashmead's types redescribed as *Parachryomalla secunda* Girault (Insecutor Inscitiae Menstruus **5**: 154. 1917).

Ceratosmicra petiolata Ashmead: 251, 369. Type in U. S. National Museum, from Chapada, Brazil. Specific name preoccupied by (*Smicra*) *Ceratosmicra petiolata* (Cresson) and *lissa* proposed to replace it by Burks (Proc. U. S. Nat. Mus. **88**: 343. 1940).

Chrysoatomus zealandicus Ashmead: 342, 370. Type in U. S. National Museum, from Swan River, Australia.

Decatomothorax gallicola Ashmead: 273, 372. Type in U. S. National Museum, from New South Wales, Australia.

Diaulus begini Ashmead: 356, 372. Type in U. S. National Museum, probably from Sherbrooke, Quebec Province, Canada, and collected by Abbé Begin. Generic name preoccupied, replaced by *Diaulinus* Schulz (Spolia Hym., p. 146. 1906). Genus discussed and species redescribed by Crawford (Proc. U. S. Nat. Mus. **43**: 183. 1912). *Diaulinus* a synonym of *Solenotus* Foerster, according to Girault (Indications in new insects . . . p. 3. 1925. Private publ.).

Eisenia mexicana Ashmead: 233, 373. Type in U. S. National Museum, from San Blas, Tepic, Mexico. Generic name preoccupied, replaced by *Secundeisenia* Schulz (Spolia Hym., p. 146, 1906).

Encyrtaspis brasiliensis Ashmead: 290, 373, 492. Type in U. S. National Museum, from Pernambuco, Brazil. Genus and species more fully described by Gahan (Proc. U. S. Nat. Mus. **71** (art. 4): 9. 1927; **94**: 363. 1943).

Epinaeoideus melanocephalus Ashmead: 374. *Nomen nudum* according to Gahan and Fagan (U. S. Nat. Mus. Bull. **124**: 55. 1923).

Epipteromalus algonquinensis Ashmead: 319, 374. Type in U. S. National Museum, from Algonquin, Ill. Ashmead's types redescribed as *Polycystus gibbus* Girault (Proc. U. S. Nat. Mus. **58**: 212. 1920). *Epipteromalus* considered a synonym of *Trichomalus* Thomson by Kurdjumov (Rev. Russ. Ent. **13**: 4. 1913).

Euophthalmomyia pallidipes Ashmead: 339, 375. Type in U. S. National Museum, from Washington, D. C.

Eutrichosoma mirabile Ashmead: 291, 375. Type in U. S. National Museum, from Helena, Mont.

Froggattia polita Ashmead: 238, 375. Type in U. S. National Museum, from Sydney, New South Wales, Australia. Generic name preoccupied, replaced by *Eufroggattia* Ashmead (Proc. Ent. Soc. Washington **6**: 126. 1904).

Hubbardiella arizonensis Ashmead: 339, 378. Type in U. S. National Museum, from Chiricahua Mountains, Ariz. Genus and species redescribed from Ashmead types as *Miromphalomyia perilampoides* Girault (Entomologist **49**: 249. 1916).

Koebelea australiensis Ashmead: 238, 378. Type in U. S. National Museum, from Sydney, New South Wales, Australia. Generic name preoccupied, replaced by *Eukoebelea* Ashmead (Proc. Ent. Soc. Washington **6**: 126. 1904).

Melanosmicra immaculata Ashmead: 251, 448. Type in collection of Carnegie Museum from Chapada, Brazil. Genus declared a synonym of *Ceratosmicra* by Burks (Proc. U. S. Nat. Mus. **88**: 343. 1940).

Mirocerus psyllae (=*peyelae*, typographical error) Ashmead: 309. Type in U. S. National Museum, from Peradeniya, Ceylon. The type specimen is plainly labeled *psyllae* and was bred from a psyllid by E. E. Green.

Mischosmicra kahlii Ashmead: 251, 381. Type in U. S. National Museum, from Lawrence, Kans. Synonym of *Ceratosmicra debilis* Say, according to Burks (Proc. U. S. Nat. Mus. **88**: 345. 1940).

Mormoniella brevicornis Ashmead: 316, 382. Type in U. S. National Museum, from Algonquin, Ill. Genotype based on same specimens as *Nasonia brevicornis* Ashmead, genotype of *Nasonia* Ashmead, according to Brues (Can. Ent. **42**: 260. 1910). Synonym of *Mormoniella vitripennis* (Walker), according to Gahan (Proc. U. S. Nat. Mus. **71** (art. 4): 5. 1927).

Nasonia brevicornis Ashmead: 317. See under *Mormoniella brevicornis* Ashmead.

Nesomyia albipes Ashmead: 344, 382. Type in U. S. National Museum, from Atami, Japan. Species redescribed as new by Ashmead (Journ. New York Ent. Soc. **12**: 161. 1904).

Notanisomorpha collaris Ashmead: 356, 382. Type in U. S. National Museum, from Cedar Point, Md. Genus and species redescribed by Crawford (Proc. U. S. Nat. Mus. **43**: 185. 1912).

Octosmicra laticeps Ashmead: 252, 382. No type specimens have been located, and the type locality is unknown. Five species from Brazil are listed on pages 450 and 451, but *laticeps* is not among them. Burks (Proc. U. S. Nat. Mus. **88**: 263. 1940) synonymized the genus with *Spilochalcis* Thomson.

Pachycrepoideus dubius Ashmead: 239, 383. Type in U. S. National Museum, from East Lansing, Mich. Genus and species fully described by Girault and Sanders (Psyche **17**: 110. 1910).

Parapteromalus isosomatis Ashmead: 320, 384. Type in U. S. National Museum, from Urbana, Ill. Ashmead's types redescribed as *Merisus carinatus* Girault (Soc. Ent. Stuttgart **31**: 57. 1916).

Parasaphes iceryae Ashmead: 328, 384. Type in U. S. National Museum, from Columba, New South Wales, Australia. Generic name preoccupied, replaced by *Parasaphodes* Schulz (Spolia Hym., p. 146. 1906). Ashmead's types redescribed as *Amiscogaster ruskini* Girault (Insecutor Inscitiae Menstruus **5**: 144. 1917).

Paraspalangia annulipes Ashmead: 334, 384. Type in U. S. National Museum, from College Station, Tex. Ashmead's types redescribed as *Stigmatotetrastichus emersoni* Girault (Ann. Ent. Soc. Amer. **9**: 304. 1916).

Paraterobia nigriceps Ashmead: 284. Type in U. S. National Museum, from Tumut, New South Wales, Australia. Ashmead types redescribed as part of the type series of *Perilampoides aurantiscutum* Girault (Mem. Queensland Mus. **5**: 224. 1917).

Pentasmicra brasiliensis Ashmead: 225, 384. Type in collection of Carnegie Museum, from Corumba, Brazil. Genus and species more fully described by Kahl (Ann. Carnegie Mus. **13**: 265. 1921). Genus declared a synonym of *Spilochalcis* Thomson by Burks (Proc. U. S. Nat. Mus. **88**: 264. 1940).

Pheidoloxenus wheeleri Ashmead: 328, 385. Type in U. S. National Museum, from Texas. Species figured and redescribed by Wheeler (Bull. Amer. Mus. Nat. Hist. **23**: 17. 1907). Ashmead types redescribed as new under the same generic and specific names by Girault (Ann. Ent. Soc. Amer. **8**: 273. 1915).

Pristosmicra sexmaculata Ashmead: 386. Neither genus nor species described, and apparently no type specimens exist. Name is a *nomen nudum*.

Schwarzella arizonensis Ashmead: 256, 388. Type in U. S. National Museum, from Arizona.

Scotolinx gallicola Ashmead: 354, 388. Type in U. S. National Museum, from Liverpool, New South Wales, Australia. Ashmead types described as new under the same generic and specific names by Girault (Mem. Queensland Mus. **5**: 218. 1916).

Scymnophagus townsendi Ashmead: 319. Types in U. S. National Museum, from San Luis and Monterey, Mexico. Genus a synonym of *Xenocrepis* Foerster, according to Kurdjumov (Rev. Russe Ent. **13**: 6. 1913). Redescribed as *Xenocrepis mexicana* Girault (Ent. News **27**: 227. 1916) with same specimens as types.

Spathopus anomalipes Ashmead: 272. Type in U. S. National Museum, from Jacksonville, Fla. Included in key to genera of Pireninae by Ferriere (Mitt. Schweiz. Ent. Ges. **16**(1): 86. 1934).

Stenomesioideus melleus Ashmead: xi, 355, 389. Type in U. S. National Museum, from Washington, D. C. Redescribed as *Stenomesioidea mellea* Girault (Proc. U. S. Nat. Mus. **51**: 43. 1916) with same specimen as type.

Stigmatocrepis americana Ashmead: 273, 389. Type in U. S. National Museum, from Jacksonville, Fla.

Stylophorella perplexa Ashmead: 275, 389. Type

in U. S. National Museum, from San Diego, Tex. Genus a synonym of *Picroscytus* Thomson, according to Crawford (Can. Ent. **41**: 98. 1909). *Picroscytus* Thomson is a synonym of *Artholysis* Foerster, according to Gahan and Fagan (U. S. Nat. Mus. Bull. **124**: 115. 1923).

Tachardiaephagus thoracicus Ashmead: 303, 390. Type in U. S. National Museum, from Ceylon. Generic and specific synonymy, references, and descriptive notes given by Ferriere (Bull. Ent. Res. **19**: 171. 1928).

Tachinaephagus zealandicus Ashmead: 304, 390. Type in U. S. National Museum, from Queanbeyan, New South Wales, Australia. Generic and specific synonymy discussed by Gahan (Proc. Ent. Soc. Washington **40**: 210. 1938).

Trichencyrtus chapadae Ashmead: 291, 392, 495. Type in collection of Carnegie Museum, from Chapada, Brazil. The type is labeled *T. robustus*, but evidently it is the specimen intended as the genotype and referred to on page 291 as *chapadae*. (See Gomes, Bol. Soc. Brasil Agronomia **5**: 287. 1942.)

Trigonogastra auratus Ashmead: 330, 392. Type in U. S. National Museum. This type bears only the label "Ac. Cat. 595A," but it is believed to have been from Lansing, Mich.

Tropidogastra arizonensis Ashmead: 323, 392. Type in U. S. National Museum, from Santa Rita Mountains, Ariz. Type redescribed as *Dinarmus arizonicus* Girault (Insecutor Inscitiae Menstruus **4**: 109. 1916). Genus synonymized with *Cheiropachus* Westwood by Gahan (Proc. Ent. Soc. Washington **40**: 220. 1938).

Uroderostenus pleuralis Ashmead: 343, 392, 511. Type lost; from St. Vincent, West Indies (H. H. Smith, collector). The type was originally deposited in the U. S. National Museum, but only the empty pin remains.

Xanthoatomus albipes Ashmead: xi, 360. Type in U. S. National Museum, from Washington, D. C. Although he published the name, Ashmead apparently never placed the name label on any specimens, but certain specimens previously standing under the generic name in the U. S. National Museum collection, as arranged by Ashmead, were without much doubt the ones to which he intended to apply the name. These specimens were remounted on slides and studied by A. A. Girault, who identified them as *Pentarthron minutum* (Riley) (Bull. Wisconsin Nat. Hist. Soc. **9**: 155. 1911), now known as *Trichogramma minutum* (Riley). Records of the Bureau of Entomology and Plant Quarantine show that these specimens were reared from eggs of *Hyphantria textor* Harris collected in the vicinity of Washington, D. C., August 18, 1883. Since these specimens are believed to be the Ashmead types and since Girault's identification appears to be correct, the genus *Xanthoatomus* Ashmead should be considered a synonym of *Trichogramma* Westwood, and the species *X. albipes* a synonym of *T. minutum* (Riley).

MAMMALOGY.—*A new Philippine rat allied to* "Bullimus" bagobus *Mearns.*[1]

DAVID H. JOHNSON. (Communicated by HERBERT FRIEDMANN.)

On the basis of a single specimen from Todaya, at 4,000 feet altitude on Mount Apo, southern Mindanao, Mearns (1905, p. 450) founded a new genus and species of rat, *Bullimus bagobus*. Thomas (1907, p. 141) recorded a second specimen from 3,000 feet altitude on the same mountain and synonymized *Bullimus* under the then broad genus *Mus*. Apparently no further specimens have been recorded. *Bullimus* has been treated subsequently as a valid genus by Hollister (1912, p. 30; 1913, p. 324) and by Taylor (1934, p. 411), and as a synonym of *Rattus* by Ellerman (1931, pp. 148, 159).

Surveys of rodents conducted in 1945 and 1946 by units of the Medical Department of the U. S. Navy in the vicinity of Guiuan, southeastern Samar Island, revealed the presence there of a closely related subspecies. The first specimen was taken at Mercedes on March 7, 1945, by Lt. Jesse E. Barker, U.S.N.R., and was added by him to a collection being made by an advance part of Naval Medical Research Unit no. 2. Subsequently Lt. (jg) Willard W. Lahnum, U.S.N.R., working in cooperation with Epidemiology Unit no. 61, collected additional specimens near Mercedes and on nearby Calicoan Island.

[1] Received July 25, 1946.

Six specimens have thus come to the United States National Museum, where they been compared with the type specimen of *bagobus*.

Rattus bagobus barkeri, n. subsp.

Type specimen.—U.S.N.M. no. 278141, young adult male, skin and skull, collected March 7, 1945, by Jesse E. Barker, prepared by D. H. Johnson, original no. 276.

Type locality.—Village of Mercedes, 5 miles north of Guiuan, southeastern Samar Island, Philippine Islands. Altitude about 200 feet. (See Fig. 1.)

Diagnosis.—Differing from *Rattus bagobus bagobus* in smaller size, sparser and less woolly pelage, predominantly gray (rather than whitish) underparts, relatively broader and more angular skull, larger audital bullae, narrower interbullar space, and smaller molar teeth.

Characters.—Size large; tail shorter than head and body; males larger than females (see Table 1). Ears large, rounded, and leathery, practically naked on both surfaces. Scales near base of tail in 9 annular rows per centimeter. Hind foot broad, sole bare to heel, tarsal part elongate, toes relatively short and stubby.

FIG. 1.—Map of the southeastern part of Samar Island, showing localities mentioned in the text.

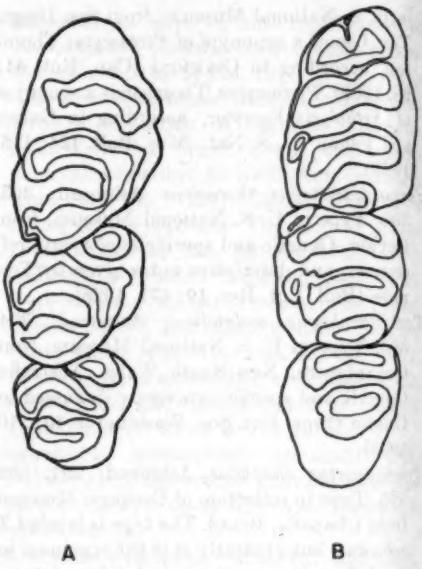


FIG. 2.—Occlusal surfaces of (*A*) right upper and (*B*) left lower molar teeth of *Rattus bagobus barkeri*, n. subsp., type specimen. ×6.

Mammary formula (in type of *bagobus* and three females of *barkeri*) 1–3 = 8.

Color of type specimen (capitalized color terms are from Ridgway, 1912): Upperparts in general Bister, in detail a mixture of black and Sayal Brown; sides paler than back, with Pinkish Cinnamon to Cinnamon hair tips underlain by Neutral Gray basal color; underparts Drab (mottled on throat and chest with Army Brown patches, which are thought to be adventitious stains); chin whitish; tail black above and below and completely to the tip (with considerable reddish-brown discoloration from the predominating coral clay of the region); feet blackish with a sprinkling of short silvery hairs; vibrissae black, extending back beyond ear. Old adult specimens are darker, near Vandyke Brown or Bone Brown on the midback; the underparts in no. 282149 are unusually pale, the hairs silvery to the base, with a variable reddish tinge resulting at least in part from adventitious staining; in no. 282146 the terminal 18 mm of the tail is yellowish white.

Skull with elongate rostrum and prolonged frontal region; nasals ending anterior to level of lacrymal processes; temporal ridges well developed, with pronounced angle at fronto-

parietal suture; incisive foramina ending anterior to root of M^1; palate narrow, ending opposite posterior edge of M^3; greatest zygomatic breadth opposite frontoparietal suture; bullae large and inflated, each with a dentlike depression on its outer side; molar pattern essentially as in type specimen of *bagobus:* upper molars with outer row of cusps reduced; no outer cusps on first lamina of M^3 and M^2; external accessory cusps anterior to third lamina of M_1 and first and second laminae of M_2 (Fig. 2).

Measurements.—See Table 1.

Distribution.—Known only from the extreme southeastern peninsula of Samar Island and from adjacent Calicoan Island (Fig. 1).

Remarks.—Other rats trapped in the vicinity of Guiuan were *Rattus everetti, R. mindanensis,* and a member of the *Rattus exulans* group; these were abundant in the casually cultivated coconut-grove and yam-patch association that characterizes the low-lying inhabited parts of the area. In contrast, *Rattus bagobus* seemed to prefer the vicinity of the native jungle, most of which was confined to the elevated coral ridges. The type specimen was taken at a place where the two associations meet, and according to information supplied by Lieutenant Lahnum, his specimens were all taken in the high forested country.

This species seems to be a specialized member of the *Rattus xanthurus* group, which is limited geographically to Celebes and the Philippine Islands. Other Philippine species of the group (see Ellerman, 1941, p. 190) are *albigularis, everetti, gala, luzonicus,* and *tagulayensis;* with these I should also place *Rattus tyrannus* Miller of Ticao Island, which has been erroneously assigned to the *Rattus norvegicus* group by Taylor (1934, p. 427) and Ellerman (1941, p. 184). All these species are represented in the U. S. National Museum, either by types or by referred specimens. From all of them *Rattus bagobus* differs in its usually unicolored tail and its elongate rostrum. The nearest relative seems to be *Rattus luzonicus* from Mount Data, Luzon, but the latter has much smaller bullae and

TABLE 1.—MEASUREMENTS IN MILLIMETERS OF SPECIMENS OF THE TWO SUBSPECIES OF RATTUS BAGOBUS

Specimen and locality	Head and body	Tail	Hind foot	Ear, from notch	Condylobasal length	Length of nasals	Zygomatic breadth	Interorbital breadth	Depth of rostrum	Length of incisive foramina	Length of auditory bullae	Length of upper molar row	Length of lower molar row
No. 278141 (♂) Mercedes, Samar *barkeri,* type	236	187	53	28	54.1	23.1	26.8	7.6	10.7	9.9	10.7	9.1	9.4
No. 282149 (♂) Mercedes, Samar *barkeri*	267	178	51	—	57.4	24.4	—	7.5	11.0	11.3	10.4	9.1	9.5
No. 282148 (♂) Calicoan I., Samar *barkeri*	254	191	54	—	58.6	25.3	—	7.9	10.8	10.6	11.0	9.2	9.4
No. 282145 (♀) Calicoan I., Samar *barkeri*	250	200	—	—	—	23.7	—	7.9	10.4	10.7	—	—	—
No. 282146 (♀) Calicoan I., Samar *barkeri*	269	175	50	—	—	—	—	—	—	—	—	—	—
No. 282147 (♀) Calicoan I., Samar *barkeri*	213	162	48	—	51.5	21.4	25.4	7.3	10.1	9.3	10.3	7.8	7.9
No. 125248 (♀) Mt. Apo, Mindanao *bagobus,* type	275[1]	128[2]	54	—	53.6	23.6	26.7	7.2	9.9	10.7	9.9	9.6	9.4

[1] External measurements from Mearns (1905, p. 451), made on dry study skin.
[2] Tail apparently incomplete.

larger molar teeth. There are no satisfactorily constant characters by which "*Bullimus*" can be retained.

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